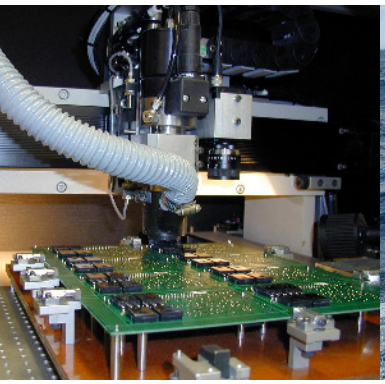
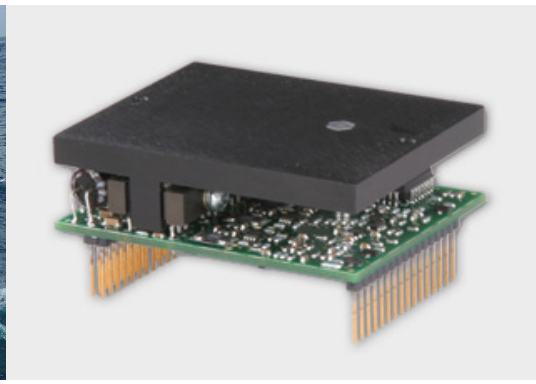
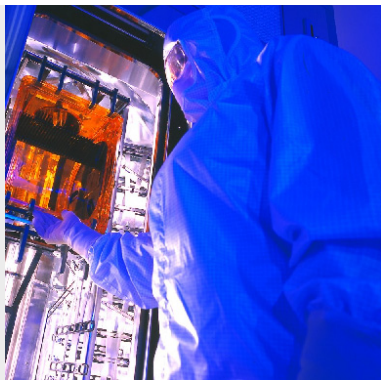
ADVANCED MOTION CONTROLS



Everything's possible.

AZ Analog Drives

for Servo Systems

Hardware

Installation Manual

Preface

ADVANCED Motion Controls constantly strives to improve all of its products. We review the information in this document regularly and we welcome any suggestions for improvement. We reserve the right to modify equipment and documentation without prior notice.

For the most recent software, the latest revisions of this manual, and copies of compliance and declarations of conformity, visit the company's website at *www.a-m-c.com*. Otherwise, contact the company directly at:

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Agency Compliances

The company holds original documents for the following:

- UL 508c, file number E140173
- Electromagnetic Compatibility, EMC Directive - 2004/108/EC
  EN61000-6-2:2005
  EN61000-6-4:2007
- Electrical Safety, Low Voltage Directive - 2006/95/EC
  EN 60204-1:2006
- Reduction of Hazardous Substances (RoHS), 2011/65/EU

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Related Documentation

- Product datasheet specific for your drive, available for download at www.a-m-c.com.

Attention Symbols

The following symbols are used throughout this document to draw attention to important operating information, special instructions, and cautionary warnings. The section below outlines the overall directive of each symbol and what type of information the accompanying text is relaying.

Note - Pertinent information that clarifies a process, operation, or ease-of-use preparations regarding the product.

Notice - Required instruction necessary to ensure successful completion of a task or procedure.

Caution - Instructs and directs you to avoid damaging equipment.

Warning - Instructs and directs you to avoid harming yourself.

Danger - Presents information you must heed to avoid serious injury or death.

Revision History

Document ID	Revision #	Date	Changes
MNALAZIN-01	1	9/2008	- AZ Install Manual First Release
MNALAZIN-02	2	10/2008	- Updated Pads Layout Diagram, Figure 3.12 - Updated Pin Layout Diagram, Figure 2.8 - Added Tachometer Velocity information (also see page 12, page 45, and page 50)
MNALAZIN-03	3	6/2009	- Added AZ_40A8 drive model information
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MNALAZIN-11	11	2/2015	- Added AZ_10A4IC drive model information
MNALAZIN-12	12	5/2015	- Added AZBH10A4 and AZBD10A4 drive model information
MNALAZIN-13	13	9/2015	- Added AZBE10A4 drive model information

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Index I

1 Safety

This section discusses characteristics of your AZ Analog Drive to raise your awareness of potential risks and hazards. The severity of consequences ranges from frustration of performance, through damage to equipment, injury or death. These consequences, of course, can be avoided by good design and proper installation into your mechanism.

1.1 General Safety Overview

In order to install an AZ drive into a servo system, you must have a thorough knowledge and understanding of basic electronics, computers and mechanics as well as safety precautions and practices required when dealing with the possibility of high voltages or heavy, strong equipment.

Observe your facility's lock-out/tag-out procedures so that work can proceed without residual power stored in the system or unexpected movements by the machine.

Notice

You must install and operate motion control equipment so that you meet all applicable safety requirements. Ensure that you identify the relevant standards and comply with them. Failure to do so may result in damage to equipment and personal injury.

Read this entire manual prior to attempting to install or operate the drive. Become familiar with practices and procedures that allow you to operate these drives safely and effectively. You are responsible for determining the suitability of this product for the intended application. The manufacturer is neither responsible nor liable for indirect or consequential damages resulting from the inappropriate use of this product.

Notice

High-performance motion control equipment can move rapidly with very high forces. Unexpected motion may occur especially during product commissioning. Keep clear of any operational machinery and never touch them while they are working.

Warning

Keep clear of all exposed power terminals (motor, DC Bus, shunt, DC power, transformer) when power is applied to the equipment. Follow these safety guidelines:

- Always turn off the main power and allow sufficient time for complete discharge before making any connections to the drive.
- Do not rotate the motor shaft without power. The motor acts as a generator and will charge up the power supply capacitors through the drive. Excessive speeds may cause over-voltage breakdown in the power output stage. Note that a drive having an internal power converter that operates from the high voltage supply will become operative.
- Do not short the motor leads at high motor speeds. When the motor is shorted, its own generated voltage may produce a current flow as high as 10 times the drive current. The short itself may not damage the drive but may damage the motor. If the connection arcs or opens while the motor is spinning rapidly, this high voltage pulse flows back into the drive (due to stored energy in the motor inductance) and may damage the drive.
- Do not make any connections to any internal circuitry. Only connections to designated connectors are allowed.
- Do not make any connections to the drive while power is applied.

Caution

- Do not reverse the power supply leads! Severe damage will result!
- If using relays or other means to disconnect the motor leads, be sure the drive is disabled before reconnecting the motor leads to the drive. Connecting the motor leads to the drive while it is enabled can generate extremely high voltage spikes which will damage the drive.

Caution

Use sufficient capacitance!

Pulse Width Modulation (PWM) drives require a capacitor on the high voltage supply to store energy during the PWM switching process. Insufficient power supply capacitance causes problems particularly with high inductance motors. During braking much of the stored mechanical energy is fed back into the power supply and charges its output capacitor to a higher voltage. If the charge reaches the drive's over-voltage shutdown point, output current and braking will cease. At that time energy stored in the motor inductance continues to flow through diodes in the drive to further charge the power supply capacitance. The voltage rise depends upon the power supply capacitance, motor speed, and inductance.

Caution

Make sure minimum inductance requirements are met!

Pulse Width modulation (PWM) servo drives deliver a pulsed output that requires a minimum amount of load inductance to ensure that the DC motor current is properly filtered. The minimum inductance values for different drive types are shown in the individual data sheet specifications. If the drive is operated below its maximum rated voltage, the minimum load inductance requirement may be reduced. Most servo-motors have enough winding inductance. Some types of motors (e.g. "basket-wound", "pancake", etc.) do not have a conventional iron core rotor, so the winding inductance is usually less than 50 µH.

If the motor inductance value is less than the minimum required for the selected drive, use an external filter card.

2 Products and System Requirements

This document is intended as a guide and general overview in selecting, installing, and operating an AZ servo drive. Contained within are instructions on system integration, wiring, drive-setup, and standard operating methods.

2.1 AZ Drive Family Overview

The family of AZ analog drives are designed to offer the same high performance and accuracy of larger drives, but in a space-saving PCB-mount architecture. By utilizing high density power devices, dual sided PCB boards, and creative design AZ drives are ideal for applications with limited size and weight constraints.

The AZ drive family contains drives that can power Single Phase (brushed) and Three Phase (brushless) motors. AZ drives are powered off a single unregulated DC power supply, and provide a variety of control and feedback options. The drives accept either a ±10V analog signal or a PWM and Direction signal as input. A digital controller can be used to command and interact with AZ drives, and a number of input/output pins are available for parameter observation and drive configuration.

TABLE 2.1 Standard AZ Drive Family Part Numbers

	Voltage	10-40V	10-80V					40-175V	
	Peak Current	10A	6A	12A	20A	40A	60A	10A	25A
Three Phase (Brushless) and Single Phase (Brushed	Current Mode Analog ±10V Command	AZB10A4 AZB10A4IC	AZB6A8	AZB12A8	AZB20A8	AZB40A8	AZB60A8	AZB10A20	AZB25A20
	Current Mode PWM / Dir Command	AZBDC10A4 AZBDC10A4IC	AZBDC6A8	AZBDC12A8	AZBDC20A8	AZBDC40A8	AZBDC60A8	AZBDC10A20	AZBDC25A20
	Hall Velocity Analog ±10V Command	AZBH10A4	AZBH6A8	AZBH12A8	AZBH20A8	AZBH40A8	AZBH60A8	AZBH10A20	AZBH25A20
	Encoder Velocity Analog ±10V Command	AZBE10A4	AZBE6A8	AZBE12A8	AZBE20A8	AZBE40A8	AZBE60A8	AZBE10A20	AZBE25A20
	Duty Cycle Mode Analog ±10V Command	AZBD10A4	-	-	-	-	-	-	-

2.1.1 Drive Datasheet

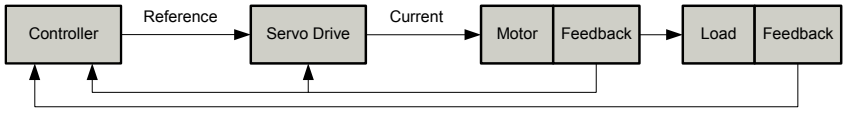
Each AZ analog drive has a separate datasheet that contains important information on the modes and product-specific features available with that particular drive. The datasheet is to be used in conjunction with this manual for system design and installation.

2.2 Analog PWM Servo Drive Basics and Theory

Analog servo drives are used extensively in motion control systems where precise control of position and/or velocity is required. The drive transmits the low-energy reference signals from the controller into high-energy signals (motor voltage and current). The reference signals can be either analog or digital, with a ±10 VDC signal being the most common. The signal can represent either a motor torque or velocity demand.

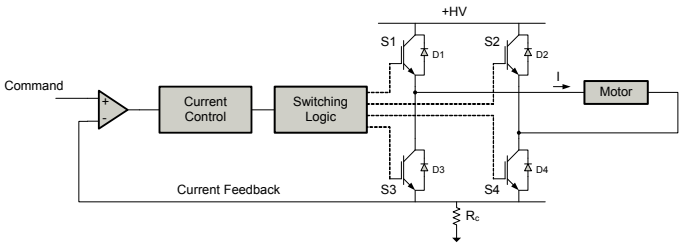
Figure 2.1 shows the components typically used in a servo system (i.e. a feedback system used to control position, velocity, and/or acceleration). The controller contains the algorithms to close the desired servo loops and also handles machine interfacing (inputs/outputs, terminals, etc.). The drive represents the electronic power converter that drives the motor according to the controller reference signals. The motor (which can be of the brushed or brushless type, rotary, or linear) is the actual electromagnetic actuator, which generates the forces required to move the load. Feedback elements are mounted on the motor and/or load in order to close the servo loop.

FIGURE 2.1 Typical Motion Control System



Although there exist many ways to "amplify" electrical signals, pulse width modulation (PWM) is by far the most efficient and cost-effective approach. At the basis of a PWM servo drive is a current control circuit that controls the output current by varying the duty cycle of the output power stage (fixed frequency, variable duty cycle). Figure 2.2 shows a typical setup for a single phase load.

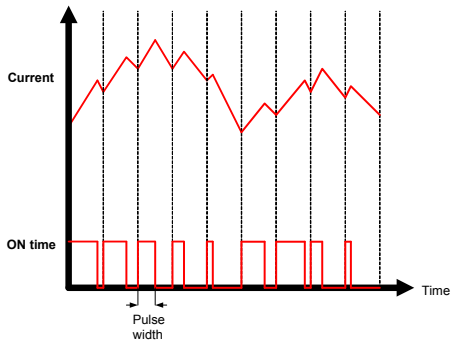
FIGURE 2.2 PWM Current Control Circuit



S1, S2, S3, and S4 are power devices (MOSFET or IGBT) that can be switched on or off. D1, D2, D3, and D4 are diodes that guarantee current continuity. The bus voltage is depicted by +HV. The resistor R_c is used to measure the actual output current. For electric motors, the load is typically inductive due to the windings used to generate electromagnetic fields. The current can be regulated in both directions by activating the appropriate switches. When switch S1 and S4 (or S2 and S3) are activated, current will flow in the positive (or negative) direction and increase. When switch S1 is off and switch S4 is on (or S2 off and S3 on) current will flow in the positive (or negative) direction and decrease (via one of the diodes). The switch "ON" time is determined by the difference between the current demand and the actual current. The current control circuit will compare both signals every time interval (typically 50 µsec or less) and activate the switches accordingly (this is done by the switching logic circuit, which also

performs basic protection functions). Figure 2.3 shows the relationship between the pulse width (ON time) and the current pattern. The current rise time will depend on the bus voltage (+HV) and the load inductance. Therefore, certain minimum load inductance requirements are necessary depending on the bus voltage.

FIGURE 2.3 Output Current and Duty Cycle Relationship



2.2.1 Single Phase (Brushed) Motors

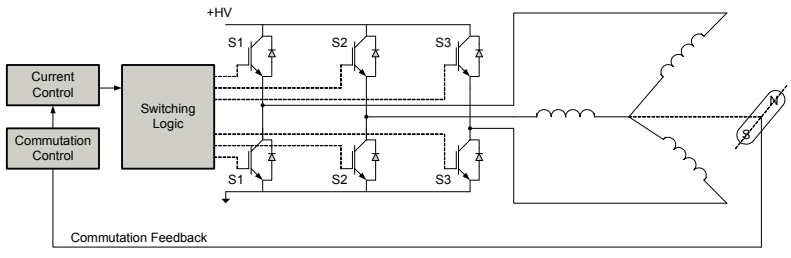
AZ servo drives are designed for use with permanent magnet brushed DC motors (PMDC motors). PMDC motors have a single winding (armature) on the rotor, and permanent magnets on the stator (no field winding). Brushes and commutators maintain the optimum torque angle. The torque generated by a PMDC motor is proportional to the current, giving it excellent dynamic control capabilities in motion control systems.

AZ drives can also be used to control current in other inductive loads such as voice coil actuators, magnetic bearings, etc.

2.2.2 Three Phase (Brushless) Motors

AZ servo drives are used with brushless servo motors. These motors typically have a three-phase winding on the stator and permanent magnets on the rotor. Brushless motors require commutation feedback for proper operation (the commutators and brushes perform this function on brush type motors). This feedback consists of rotor magnetic field orientation information, supplied either by magnetic field sensors (Hall Effect sensors) or position sensors (encoder or resolver). Brushless motors have better power density ratings than brushed motors because heat is generated in the stator, resulting in a shorter thermal path to the outside environment. Figure 2.4 shows a typical system configuration.

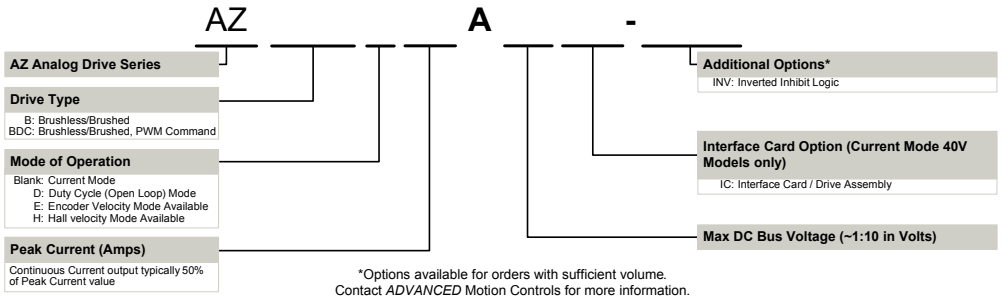
FIGURE 2.4 Brushless Servo System



2.3 Products Covered

The products covered in this manual adhere to the following part numbering structure. However, additional features and/or options are readily available for OEM's with sufficient ordering volume. Feel free to contact *ADVANCED* Motion Controls for further information.

FIGURE 2.5 AZ Part Numbering Structure


AZ
A
-
AZ Analog Drive Series
Drive Type
B: Brushless/Brushed
BDC: Brushless/Brushed, PWM Command
Mode of Operation
Blank: Current Mode
D: Duty Cycle (Open Loop) Mode
E: Encoder Velocity Mode Available
H: Hall velocity Mode Available
Peak Current (Amps)
Continuous Current output typically 50% of Peak Current value
Additional Options*
INV: Inverted Inhibit Logic
Interface Card Option (Current Mode 40V Models only)
IC: Interface Card / Drive Assembly
Max DC Bus Voltage (~1:10 in Volts)
*Options available for orders with sufficient volume.
Contact ADVANCED Motion Controls for more information.

In general, the AZ family of analog drives can be divided into top-level categories based on the peak current rating of the drive. These categories can be further separated into subdivisions based on specifications such as whether a drive uses analog or PWM input and the feedback available on the drive.

TABLE 2.2 Power Specifications

Power Specifications									
Description	**Units**	**AZ_10A4xx**	**AZ_6A8**	**AZ_12A8**	**AZ_20A8**	**AZ_40A8**	**AZ_60A8**	**AZ_10A20**	**AZ_25A20**
DC Supply Voltage Range	VDC	10-36	20-80		10-80			40-175	
DC Bus Over Voltage Limit	VDC	40	88					195	193
DC Bus Under Voltage Limit	VDC	8	18		9			36	
Maximum Peak Output Current	A	10	6	12	20	40	60	10	25
Maximum Continuous Output Current	A	5	3	6	12	20	30	6	12.5
Maximum Power Dissipation at Continuous Current	W	9	12	24	48	80	120	53	110
Minimum Load Inductance	µH	100	100					250	
Switching Frequency[1]	kHz	40	31					20.7	

1. Switching frequency for AZBE/AZBH_40A8 and AZBE/AZBH_60A8 drive models is 33 kHz. Switching frequency for AZBE/AZBH_10A20 and AZBE/AZBH_25A20 is 22 kHz.

TABLE 2.3 Control Specifications

Control Specifications					
Description	**AZB**	**AZBDC**	**AZBE[1]**	**AZBH[2]**	**AZBD**
Command Sources	± 10V Analog	PWM and Direction	± 10V Analog	± 10V Analog	± 10V Analog
Commutation Methods	Trapezoidal	Trapezoidal	Trapezoidal	Trapezoidal	Trapezoidal
Control Modes	Current	Current	Current, Duty Cycle, Encoder Velocity, Tachometer Velocity	Current, Duty Cycle, Hall Velocity, Tachometer Velocity	Duty Cycle
Motors Supported	Three Phase Single Phase	Three Phase Single Phase	Three Phase Single Phase	Three Phase Single Phase	Three Phase Single Phase

1. AZBE10A4 models operate solely in Encoder Velocity mode.
2. AZBH10A4 models operate solely in Hall Velocity mode.

2.4 Control Modes

The AZ family of analog drives offers a variety of different control methods. While some drives in the series are designed to operate solely in one mode, on other drives it is possible to select the control method by DIP switch settings. Consult the datasheet for the drive in use to see which modes are available for use.

The name of the mode refers to which servo loop is being closed in the drive, not the end-result of the application. For instance, a drive operating in Current (Torque) Mode may be used for a positioning application if the external controller is closing the position loop. Oftentimes, mode selection will be dependent on the requirements and capabilities of the controller being used with the drive as well as the end-result application.

2.4.1 Current (Torque)

In Current (Torque) Mode, the input command voltage controls the output current. The drive will adjust the output duty cycle to maintain the commanded output current. This mode is used to control torque for rotary motors (force for linear motors), but the motor speed is not controlled. The output current can be monitored through an analog current monitor output pin. The voltage value read at the "Current Monitor Output" can be multiplied by a scaling factor found on the drive datasheet to determine the actual output current. All AZ drives are able to operate in Current (Torque) Mode.

Note

While in Current (Torque) Mode, the drive will maintain a commanded torque output to the motor based on the input reference command. Sudden changes in the motor load may cause the drive to be outputting a high torque command with little load resistance, causing the motor to spin rapidly. Therefore, Current (Torque) Mode is recommended for applications using a digital position controller to maintain system stability.

2.4.2 Duty Cycle (Open Loop)

In Duty Cycle Mode, the input command voltage controls the output PWM duty cycle of the drive, indirectly controlling the output voltage. However, any fluctuations of the DC power supply voltage will affect the voltage output to the motor. This mode is available as a DIP switch selectable mode on AZBE and AZBH drives, and is the sole mode of operation on the AZBD10A4 model.

Note

This mode is recommended as a method of controlling the motor velocity when precise velocity control is not critical to the application, and when actual velocity feedback is unavailable.

2.4.3 Hall Velocity

In Hall Velocity Mode, the input command voltage controls the motor velocity, with the Hall Sensor frequency closing the velocity loop. An analog velocity monitor output allows observation of the actual motor speed through a Hz/V scaling factor found on the drive datasheet. The voltage value read at the velocity monitor output can be used to determine the motor RPM through the scaling factor. See "Velocity Monitor Output" on page 50 for the motor RPM equation. This mode is available as a DIP switch selectable mode on AZBH drives, and is the sole mode of operation on the AZBH10A4 model.

Note

Due to the inherent low resolution of motor mounted Hall Sensors, Hall Velocity Mode is not recommended for low-speed applications below 300 rpm for a 6-pole motor, 600 rpm for a 4-pole motor, or 900 rpm for a 2-pole motor. Hall Velocity Mode is better suited for velocity control applications where the motor will be spinning at higher speeds.

2.4.4 Encoder Velocity

In Encoder Velocity Mode, the input command controls the motor velocity, with the frequency of the encoder pulses closing the velocity loop. An analog velocity monitor output allows observation of the actual motor speed through a kHz/V scaling factor found on the drive datasheet. The voltage value read at the velocity monitor output can be used to determine the motor RPM through the scaling factor. See "Velocity Monitor Output" on page 50 for the motor RPM equation. This mode is available as a DIP switch selectable mode on AZBE drives.

Note

The high resolution of motor mounted encoders allows for excellent velocity control and smooth motion at all speeds. Encoder Velocity mode should be used for applications requiring precise and accurate velocity control, and is especially useful in applications where low-speed smoothness is the objective.

2.4.5 Tachometer Velocity

In Tachometer Velocity Mode, the input command voltage controls the motor velocity. This mode uses an external DC tachometer to close the velocity loop. The drive translates the DC voltage from the tachometer into motor speed and direction information. This mode is available as a DIP switch selectable mode on AZBE and most AZBH drives.

Note

DC Tachometers have infinite resolution, allowing for extremely accurate velocity control. However, they also may be susceptible to electrical noise, most notably at low speeds.

2.5 Feedback Supported

There are a number of different feedback options available in the AZ family of analog drives. The feedback element can be any device capable of generating a voltage signal proportional to current, velocity, position, or any parameter of interest. Such signals can be provided directly by a potentiometer or indirectly by other feedback devices such as Hall Sensors or Encoders. These latter devices must have their signals converted to a DC voltage, a task performed by the AZ drive circuitry.

TABLE 2.4 Feedback Supported

	Feedback Supported				
Description	**AZB**	**AZBDC**	**AZBE**	**AZBH**	**AZBD**
Hall Sensors for Commutation	✔	✔	✔	✔	✔
Hall Sensors for Velocity Control				✔	
Single- Ended Incremental Encoder			✔		

2.5.1 Feedback Polarity

The feedback element must be connected for *negative* feedback. This will cause a difference between the command signal and the feedback signal, called the *error signal*. The drive compares the feedback signal to the command signal to produce the required output to the load by continually reducing the error signal to zero. For AZ drives, this becomes important when using "Encoder Feedback" and "Hall Sensors", as connecting these feedback elements for positive feedback will lead to a motor "run-away" condition. In a case where the feedback lines are connected to the drive with the wrong polarity in either Hall Velocity or Encoder Velocity Mode, the drive will attempt to correct the "error signal" by applying more command to the motor. With the wrong feedback polarity, this will result in a positive feedback run-away condition. To correct this, either change the order that the feedback lines are connected to the drive, or change Switch 4 on the DIP switch bank to the opposite setting to reverse the internal feedback velocity polarity. See the drive datasheet for more information on DIP switch settings.

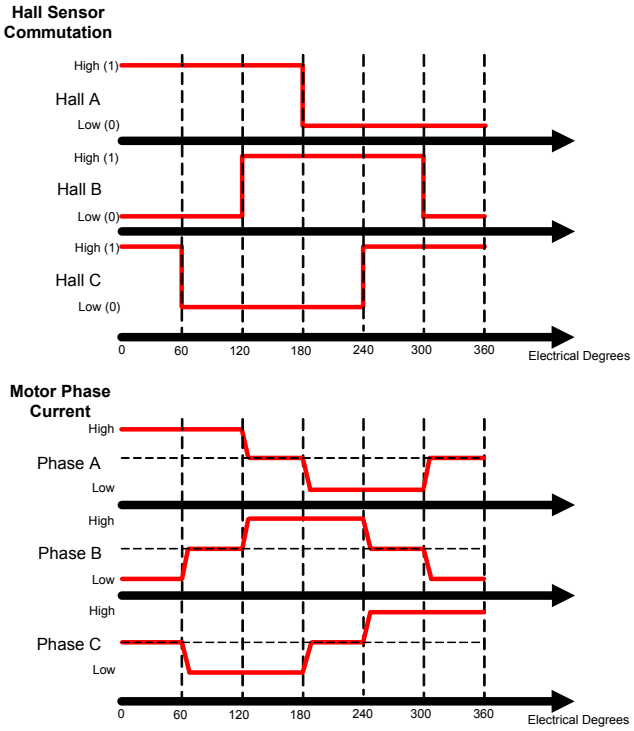
2.5.2 Hall Sensors

AZ drives use single-ended Hall Sensors for commutation feedback, and in the special case of the AZBH drives, for velocity control. The Hall Sensors (typically three) are built into the motor to detect the position of the rotor magnetic field. These sensors are mounted such that they each generate a square wave with 120-degree phase difference over one electrical cycle of the motor. Depending on the motor pole count, there may be more than one electrical cycle for every motor revolution. For every actual mechanical motor revolution, the number of electrical cycles will be the number of motor poles divided by two. For example:

- a 6-pole motor contains 3 electrical cycles per motor revolution
- a 4-pole motor contains 2 electrical cycles per motor revolution
- a 2-pole motor contains 1 electrical cycle per motor revolution

The drive powers two of the three motor phases with DC current during each specific Hall Sensor state:

FIGURE 2.6 Hall Sensor Commutation and Motor Phase Current for 120-Degree Phasing



Note: Not all *ADVANCED* Motion Controls' servo drive series use the same commutation logic. The commutation diagrams provided here should be used only with drives covered within this manual.

The table below shows the valid commutation states for both 120-degree and 60-degree phasing.

TABLE 2.5 Commutation Sequence Table

	60 Degree			120 Degree			Motor		
	Hall 1	Hall 2	Hall 3	Hall 1	Hall 2	Hall 3	Phase A	Phase B	Phase C
Valid	1	0	0	1	0	0	HIGH	-	LOW
	1	1	0	1	1	0	-	HIGH	LOW
	1	1	1	0	1	0	LOW	HIGH	-
	0	1	1	0	1	1	LOW	-	HIGH
	0	0	1	0	0	1	-	LOW	HIGH
	0	0	0	1	0	1	HIGH	LOW	-
Invalid	1	0	1	1	1	1	-	-	-
	0	1	0	0	0	0	-	-	-

By default, AZ drives are always set to 120-degree phasing. However, AZ drives feature either a surface-mount jumper (JE2) on the drive PCB that can be removed to manually set the drive to 60-degree phasing, or a DIP Switch that can configure the drive for 60-degree phasing.

Using a Single Phase Motor AZ drives are also compatible with Single Phase (Brushed) motors. However, because there are no Hall Sensors on a brushed motor, one of the following course of actions must be taken to properly commutate the drive:

- Remove the JE2 jumper to set the drive for 60-degree phasing . Leave all the Hall Sensor inputs on the drive open. These inputs are internally pulled high to +5V, creating a "1-1-1" commutation state (see Table 2.5 above) which is a valid state in 60-degree phasing. Connect only two of the motor output wires, Motor A and Motor B.

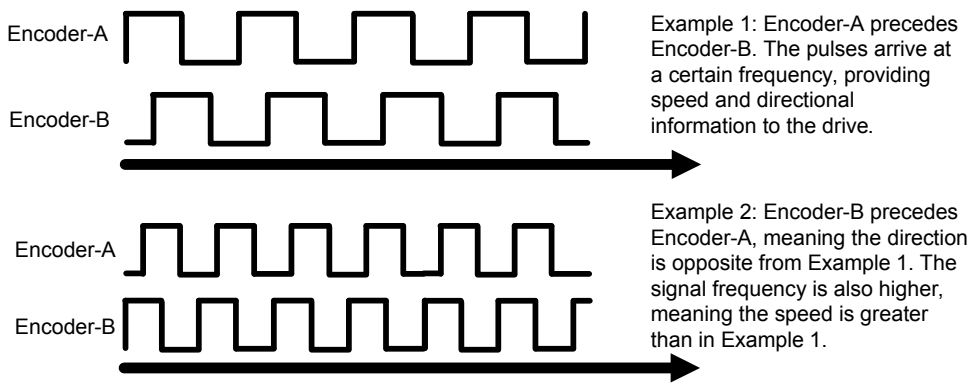
or:

- Tie one of the Hall Sensor inputs on the AZ drive to signal ground. Since the Hall Sensor inputs are by default internally brought high to +5V, this will put the AZ drive in a commutation state where two Hall inputs are high, and one is low (as shown in Table 2.5, having all three Hall inputs pulled high is an invalid commutation state in 120-degree phasing). Depending on which Hall Sensor input is tied to ground, consult Table 2.5 above to determine which two motor output wires will be conducting current for that specific commutation state.
- On AZB10A4IC drives, set DIP Switch 1 to ON (internally pulls Hall 2 to ground), and leave all the Hall Sensor inputs on the drive open. This creates a "1-0-1" commutation state, which is valid for 120-degree phasing.Connect only Motor A and Motor B.

2.5.3 Encoder Feedback

AZBE drives utilize two single-ended incremental encoder inputs for velocity control. The encoder provides incremental position feedback that can be extrapolated into very precise velocity information. The encoder signals are read as "pulses" that the AZ drive uses to essentially keep track of the motor's position and direction of rotation. Based on the speed and order in which these pulses are received from the two encoder signals, the drive can interpret the motor velocity. The diagram below represents encoder "pulse" signals, showing how dependent on which signal is read first and at what frequency the "pulses" arrive, the speed and direction of the motor shaft can be extrapolated.

FIGURE 2.7 Encoder Feedback Signals


Encoder-A
Encoder-B
Example 1: Encoder-A precedes Encoder-B. The pulses arrive at a certain frequency, providing speed and directional information to the drive.
Encoder-A
Encoder-B
Example 2: Encoder-B precedes Encoder-A, meaning the direction is opposite from Example 1. The signal frequency is also higher, meaning the speed is greater than in Example 1.

2.5.4 Tachometer Feedback

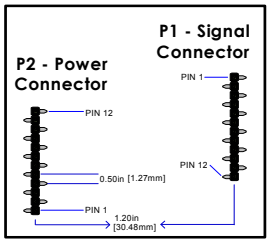
AZBE and most AZBH drives offer the option of using a DC Tachometer for velocity control. The tachometer provides an analog DC voltage feedback signal that is related to the actual motor speed and direction. The drive subsequently adjusts the output current based on the error between the tachometer feedback and the input command voltage. The maximum range of the tachometer feedback signal is ±60 VDC.

2.6 Pin Layout

The diagrams below show the pin layout and location on AZ drives, as seen from the PCB where the drive is mounted. Note that some drives use a double row for the power header, and other drives have two power connectors. More detailed dimensional information can be found in "Physical Dimensions" on page 64 and in "Mating Connectors" on page 37.

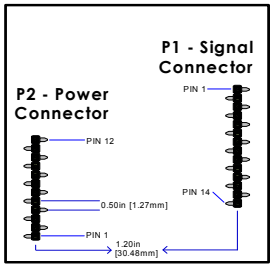
FIGURE 2.8 AZ-series Pin Layouts

AZB10A4 and AZBDC10A4 Drives

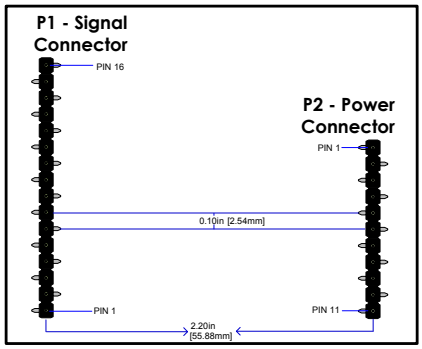


Note that P1 and P2 are identical 12-pin headers on AZB10A4 and AZBDC10A4 drive models. To avoid damage to the drive, be sure when plugging or soldering the drive into a PCB or interface card that the drive orientation is correct. P1 and P2 are labeled on the PCB silkscreen. Pin 7 on P2 is keyed (removed) to differentiate it from P1.

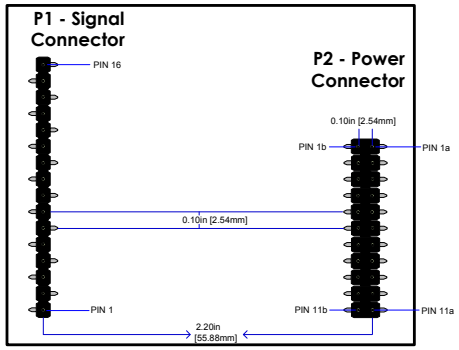
AZBE/D/H10A4 Drives



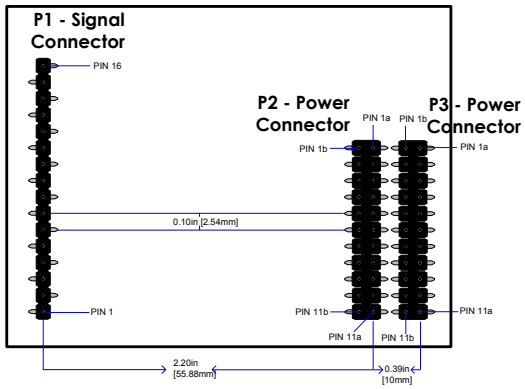
AZ_6A8 and AZ_12A8 Drives



AZ_10A20 and AZ_20A8 Drives



AZ_25A20, AZ_40A8, and AZ_60A8 Drives



2.7 Features and Control Specifications

2.7.1 AZB

- Designed to drive brushless/brushed motors with a ±10 V analog input
- Current (Torque) Mode
- Hall Sensor trapezoidal Commutation

2.7.2 AZBDC

- Designed to drive brushless/brushed motors with a PWM input command
- Current (Torque) Mode
- Hall Sensor trapezoidal Commutation

2.7.3 AZBE

- Designed to drive brushless/brushed motors with a ±10 V analog input
- DIP Switch selectable modes - Current (Torque), Duty Cycle, Encoder Velocity, Tachometer Velocity
- Hall Sensor trapezoidal commutation
- Single-ended incremental encoder feedback for velocity control
- External potentiometer input pin for command offset adjustment

2.7.4 AZBH

- Designed to drive brushless/brushed motors with a ±10 V analog input
- DIP Switch selectable modes - Current (Torque), Duty Cycle, Hall Velocity, Tachometer Velocity
- Hall Sensor trapezoidal commutation
- Single-ended Hall Sensor feedback for velocity control
- External potentiometer input pin for command offset adjustment

2.7.5 Block Diagrams

FIGURE 2.9 AZB Drive Structure

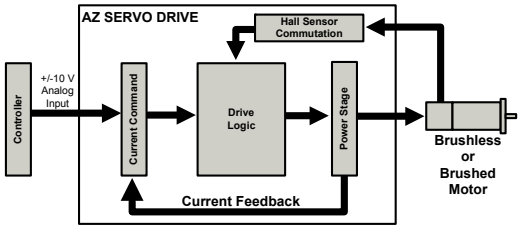


FIGURE 2.10 AZBDC Drive Structure

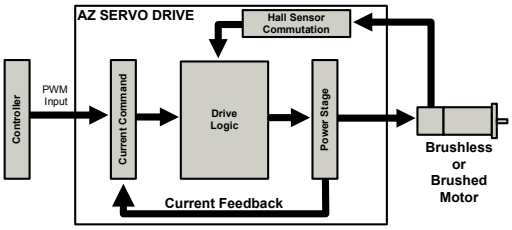


FIGURE 2.11 AZBE Drive Structure

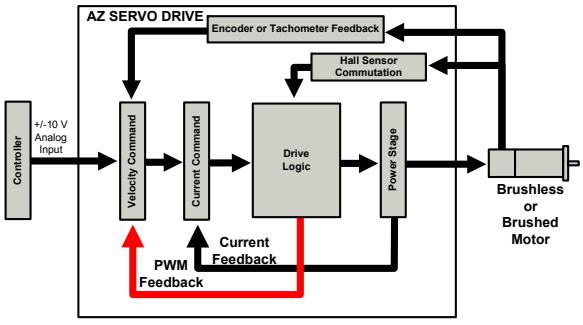
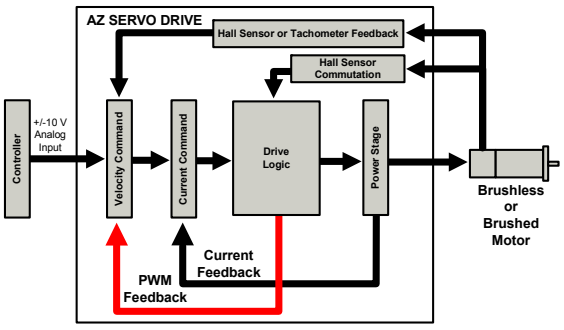


FIGURE 2.12 AZBH Drive Structure



2.7.6 Pinouts

TABLE 2.6 Signal Connectors

AZ_6A8, AZ_12A8, AZ_20A8, AZ_40A8, AZ_60A8, AZ_10A20, AZ_25A20				
P1	Analog Input	PWM Input	Analog Input Encoder Vel.	Analog Input Hall Vel.
Pin	Description	Description	Description	Description
1	+REF IN	PWM IN	+REF IN	+REF IN
2	SIGNAL GND	SIGNAL GND	SIGNAL GND	SIGNAL GND
3	-REF IN	DIR IN	-REF IN	-REF IN
4	CURRENT MONITOR	CURRENT MONITOR	CURRENT MONITOR	CURRENT MONITOR
5	INHIBIT IN	INHIBIT IN	INHIBIT IN	INHIBIT IN
6	+V HALL OUT	+V HALL OUT	+V HALL OUT	+V HALL OUT
7	SIGNAL GND	SIGNAL GND	SIGNAL GND	SIGNAL GND
8	HALL 1	HALL 1	HALL 1	HALL 1
9	HALL 2	HALL 2	HALL 2	HALL 2
10	HALL 3	HALL 3	HALL 3	HALL 3
11	CURRENT REF OUT	CURRENT REF OUT	CURRENT REF OUT	CURRENT REF OUT
12	FAULT OUT	FAULT OUT	FAULT OUT	FAULT OUT
13	RESERVED	RESERVED	ENCODER-B	RESERVED
14	RESERVED	RESERVED	ENCODER-A	RESERVED
15	RESERVED	RESERVED	VEL. MON. OUT or TACH IN	VEL. MON. OUT or TACH IN
16	RESERVED	RESERVED	OFFSET	+REF IN

AZ_10A4xx				
P1/P3	Analog Input	PWM Input	Encoder Velocity	Hall Velocity / Duty Cycle
Pin	Description	Description	Description	Description
1	-REF IN	DIR IN	ENCODER-B	RESERVED
2	+REF IN	PWM IN	ENCODER-A	RESERVED
3	SIGNAL GND	SIGNAL GND	-REF IN	-REF IN
4	FAULT OUT	FAULT OUT	+REF IN	+REF IN
5	INHIBIT IN	INHIBIT IN	SIGNAL GND	SIGNAL GND
6	CURRENT MONITOR	CURRENT MONITOR	FAULT OUT	FAULT OUT
7	HALL 3	HALL 3	INHIBIT IN	INHIBIT IN
8	HALL 2	HALL 2	CURRENT MONITOR	CURRENT MONITOR
9	HALL 1	HALL 1	HALL 3	HALL 3
10	+V HALL OUT	+V HALL OUT	HALL 2	HALL 2
11	SIGNAL GND	SIGNAL GND	HALL 1	HALL 1
12	RESERVED	RESERVED	+V HALL OUT	+V HALL OUT
13	N/A	N/A	SIGNAL GND	SIGNAL GND
14	N/A	N/A	VEL. MON. OUT	VEL. MON. OUT

TABLE 2.7 Three Phase Power Connectors

AZ_6A8, AZ_12A8 - P2	
Pin	Description
1	HIGH VOLTAGE
2	
3	NC (KEY)
4	POWER GROUND
5	
6	MOTOR C
7	
8	MOTOR B
9	
10	MOTOR A
11	

AZ_20A8, AZ_10A20 - P2 AZ_40A8, AZ_60A8, AZ_25A20 - P2,P3		
Pin		Description
1b	1a	HIGH VOLTAGE
2b	2a	
3b	3a	RESERVED (3b)
		NC - KEY (P2-3a)
4b	4a	POWER GROUND
5b	5a	
6b	6a	MOTOR C
7b	7a	
8a	8b	MOTOR B
9b	9a	
10b	10a	MOTOR A
11b	11a	

AZ_10A4 - P2	
Pin	Description
1	MOTOR A
2	
3	MOTOR B
4	
5	MOTOR C
6	
7	RESERVED
8	POWER GROUND
9	
10	HIGH VOLTAGE
11	
12	RESERVED

AZ_10A4IC - P7	
Pin	Description
1	POWER GROUND
2	
3	HIGH VOLTAGE
4	

AZ_10A4IC - P8	
Pin	Description
1	MOTOR A
2	
3	MOTOR B
4	
5	MOTOR C
6	
7	RESERVED
8	

2.8 System Requirements

To successfully incorporate an AZ servo drive into your system, you must be sure it will operate properly based on electrical, mechanical, and environmental specifications, follow some simple wiring guidelines, and perhaps make use of some accessories in anticipating impacts on performance. Before selecting an AZ servo drive, a user should consider the requirements of their system. This involves calculating the required voltage, current, torque, and power requirements of the system, as well as considering the operating environment and any other equipment the drive will be interfacing with.

Note

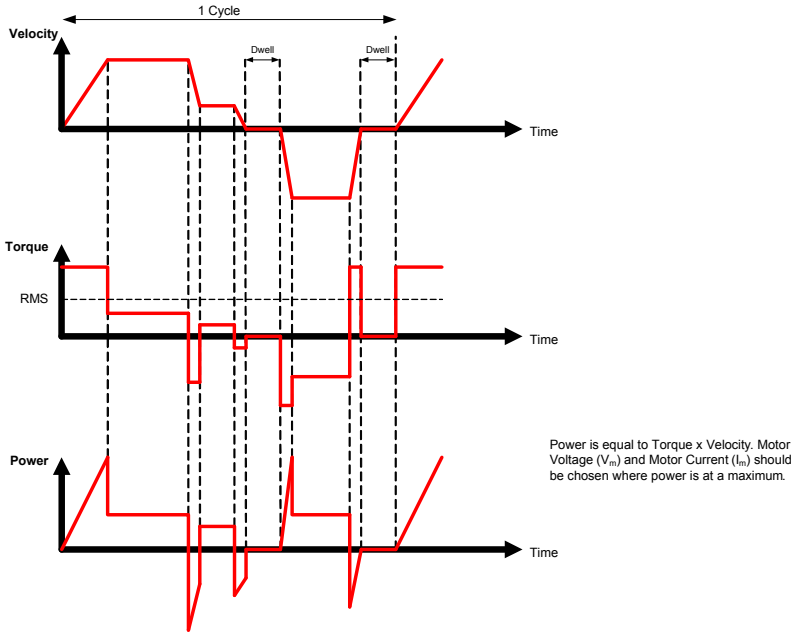
AZ servo drives are shipped with no other connectors or mounting components other than the signal and power header pins on the drive PCB itself. However, mounting cards and mating connectors are readily available. See "Mounting Cards" on page 34 for the *ADVANCED* Motion Controls AZ mounting cards. Customized mounting options are also available for orders with sufficient volume.

2.8.1 Analog Servo Drive Selection and Sizing

AZ servo drives have a given current and voltage rating unique to each drive. Based on the necessary application requirements and the information from the datasheet of the motor being used, a drive may be selected that will best suit the motor capabilities. A drive should be selected that will meet the peak and continuous current requirements of the application, and operate within the voltage requirements of the system.

Motor Current and Voltage Motor voltage and current requirements are determined based on the maximum required torque and velocity. These requirements can be derived from the application move profiles (Figure 2.13).

FIGURE 2.13 Example Velocity, Torque, and Power Curves



The **motor current I_M** is the required motor current in amps DC, and is related to the torque needed to move the load by the following equation:

$$I_M = \frac{Torque}{K_T}$$

Where:

K_T -motor torque constant

The motor current will need to be calculated for both continuous and peak operation. The peak torque will be during the acceleration portion of the move profile.

The continuous torque is the average torque required by the system during the move profile, including dwell times. Both peak torque and continuous, or RMS (root mean square) torque need to be calculated. RMS torque can be calculated by plotting torque versus time for one move cycle.

$$T_{RMS} = \sqrt{\frac{\sum_i T_i^2 t_i}{\sum_i t_i}}$$

Here T_i is the torque and t_i is the time during segment i. In the case of a vertical application make sure to include the torque required to overcome gravity.

The system voltage requirement is based on the motor properties and how fast and hard the motor is driven. The system voltage requirement is equal to the **motor voltage**, **V_M**, required to achieve the move profile. In general, the motor voltage is proportional to the motor speed and the motor current is proportional to the motor shaft torque. Linear motors exhibit the same behavior except that in their case force is proportional to current. These relationships are described by the following equations:

$$V_m = I_m R_m + E$$

$$E = K_e S_m$$

for rotary motors $$T = K_t I_m$$

for linear motors $$F = K_f I_m$$

Where:

V_m	-motor voltage
I_m	-motor current (use the maximum current expected for the application)
R_m	-motor line-to-line resistance
E	-motor back-EMF voltage
T	-motor torque
F	-motor force
K_t	-motor torque constant
K_f	-motor force constant
K_e	-voltage constant
S_m	-motor speed (use the maximum speed expected for the application)

The motor manufacturer's data sheet contain K_t (or K_f) and K_e constants. Pay special attention to the units used (metric vs. English) and the amplitude specifications (peak-to-peak vs. RMS, phase-to-phase vs. phase-to-neutral).

The maximum motor terminal voltage and current can be calculated from the above equations. For example, a motor with a K_e = 10V/Krpm and required speed of 3000 RPM would require 30V to operate. In this calculation the IR term (voltage drop across motor winding resistance) is disregarded. Maximum current is maximum torque divided by K_t. For example, a motor with K_t = 0.5 Nm/A and maximum torque of 5 Nm would require 10 amps of current. Continuous current is RMS torque divided by K_t.

Motor Inductance

The motor inductance is vital to the operation of AZ servo drives, as it ensures that the DC motor current is properly filtered.

Caution

A motor that does not meet the rated minimum inductance value of the drive may damage the drive! If the motor inductance value is less than the minimum required for the selected drive, use of an external filter card is necessary. See "Inductive Filter Cards" on page 30 for more information.

A minimum motor inductance rating for each specific drive can be found in the drive datasheet. If the drive is operated below the maximum rated voltage, the minimum load inductance requirement may be reduced.

In the above equations the motor inductance is neglected. In brushless systems the voltage drop caused by the motor inductance can be significant. This is the case in high-speed applications if motors with high inductance and high pole count are used. Please use the following equation to determine motor terminal voltage (must be interpreted as a vector).

$$V_m = (R_m + j\omega L)I_m + E$$

Where:

L	-phase-to-phase motor inductance
ω	-maximum motor current frequency

2.8.2 Power Supply Selection and Sizing

There are several factors to consider when selecting a power supply for an AZ servo drive.

- Power Requirements
- Isolation
- Regeneration
- Voltage Ripple

Power Requirements refers to how much voltage and current will be required by the drive in the system. Isolation refers to whether the power supply needs an isolation transformer. Regeneration is the energy the power supply needs to absorb during deceleration. Voltage Ripple is the voltage fluctuation inherent in unregulated supplies.

Power Supply Current and Voltage The power supply current rating is based on the maximum current that will be required by the system. If the power supply powers more than one drive, then the current requirements for each drive should be added together. Due to the nature of servo drives, the current into the drive does not always equal the current out of the drive. However, the power in is equal to the power out. Use the following equation to calculate the power supply output current, I_{PS}, based on the motor voltage and current requirements.

$$I_{PS} = \frac{V_M \cdot I_M}{V_{PS} \cdot (0.98)}$$

Where:

V_{PS}	-nominal power supply voltage
I_M	-motor current
V_M	-motor voltage

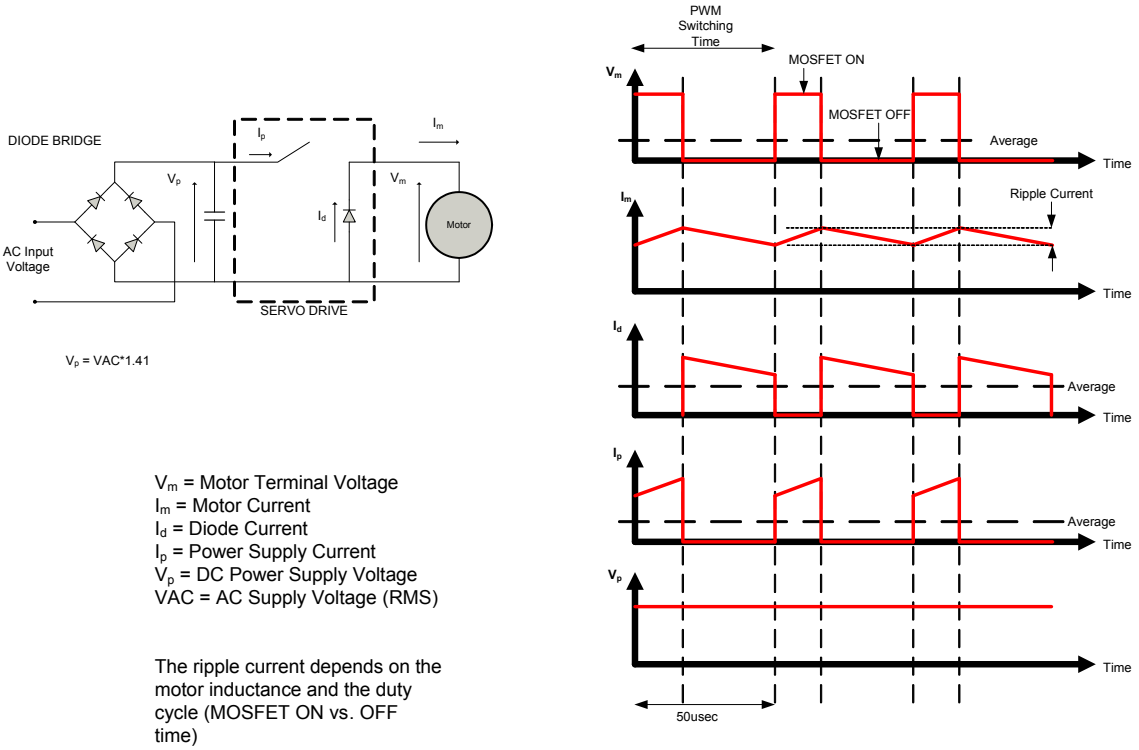
Use values of V_m and I_m at the point of maximum power in the move profile, Figure 2.13 (when $V_M I_M$ = max). This will usually be at the end of a hard acceleration when both the torque and speed of the motor is high.

The power supply current is a pulsed DC current (Figure 2.14): when the MOSFET switch is on, it equals the motor current; when the MOSFET is off it is zero. Therefore, the power supply current is a function of the PWM duty cycle and the motor current (e.g. 30% duty cycle and 12 amps motor current will result in 4 amps power supply current). 30% duty cycle also means that the average motor voltage is 30% of the DC bus voltage. Power supply power is approximately equal to drive output power plus 3 to 5%.

Caution

The only time the power supply current needs to be as high as the drive output current is if the move profile requires maximum current at maximum velocity. In many cases however, maximum current is only required at start up and lower currents are required at higher speeds.

FIGURE 2.14 Unregulated DC Power Supply Current



V_p = VAC*1.41

V_m = Motor Terminal Voltage
I_m = Motor Current
I_d = Diode Current
I_p = Power Supply Current
V_p = DC Power Supply Voltage
VAC = AC Supply Voltage (RMS)

The ripple current depends on the motor inductance and the duty cycle (MOSFET ON vs. OFF time)

A system will need a certain amount of voltage and current to operate properly. If the power supply has too little voltage/current the system will not perform adequately. If the power supply has too much voltage the drive may shut down due to over voltage, or the drive may be damaged.

To avoid nuisance over- or under-voltage errors caused by fluctuations in the power supply, the ideal system power supply voltage should be at least 10% above the entire system voltage requirement, and at least 10% below the lowest value of the following:

- Drive over voltage
- External shunt regulator turn-on voltage (see "Regeneration and Shunt Regulators" on page 21)

These percentages also account for the variances in K_t and K_e, and losses in the system external to the drive. The selected margin depends on the system parameter variations.

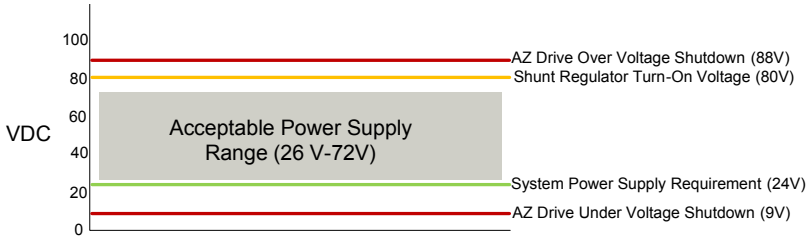
Caution

Do not select a supply voltage that could cause a mechanical over-speed in the event of a drive malfunction or a runaway condition.

Brushed Motors may have voltage limitations due to the mechanical commutators. Consult the manufacturer's data sheets.

AZ servo drives operate off an isolated unregulated DC Power Supply (see Table 2.2 for drive model power supply ranges and over-voltage shutdown values). Figure 2.15 provides one possible example of an appropriate system power supply voltage for an AZ_20A8 drive using an external shunt regulator. The shunt regulator turn-on voltage was chosen at an appropriate level to clamp the power supply voltage so it will not exceed the drive over voltage limit during regeneration. The system power supply requirement is based on the motor properties and how much voltage is needed to achieve the application move profile (see "Motor Current and Voltage" on page 16). Keep in mind that the calculated value for V_m is the minimum voltage required to complete moves at the desired speed and torque. There should be at least 10% headroom between the calculated value and the actual power supply voltage to allow for machine changes such as increased friction due to wear, change in load, increased operating speed, etc.

FIGURE 2.15 AZ_20A8 Power Supply Selection



Isolation

In systems where an AC line is involved, isolation is required between the AC line and the signal pins on the drive. This applies to all systems except those that use a battery as a power supply. There are two options for isolation:

1. The drive can have built in electrical isolation.
2. The power supply can provide isolation (e.g. a battery or an isolation transformer).

The system must have at least one of these options to operate safely.

Isolation Ordering Option

ADVANCED Motion Controls AZ drives can be ordered with isolation as an option. Specify an "I" after the current rating in the part number (i.e. AZB20A8I) to order a drive with isolation.

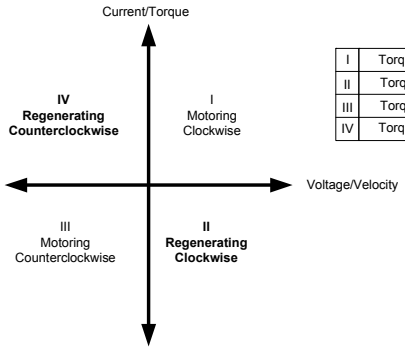
Power Supply with Isolation

An isolated power supply is either a battery or a power supply that uses an isolation transformer to isolate the AC line voltage from the power supply ground. This allows both the power ground on an isolated power supply and the signal ground on a non-isolated drive to be safely pulled to earth ground. Always use an isolated power supply if there is no isolation in the drive.

Regeneration and Shunt Regulators

Use of a shunt regulator is necessary in systems where motor deceleration or a downward motion of the motor load will cause the system's mechanical energy to be regenerated via the drive back onto the power supply.

FIGURE 2.16 **Four Quadrant Operation - Regeneration occurs when Torque and Velocity polarity are opposite**



I	Torque +	Velocity +	No Regen
II	Torque -	Velocity +	Regen
III	Torque -	Velocity -	No Regen
IV	Torque +	Velocity -	Regen

This regenerated energy can charge the power supply capacitors to levels above that of the drive over-voltage shutdown level. If the power supply capacitance is unable to handle this excess energy, or if it is impractical to supply enough capacitance, then an external shunt regulator must be used to dissipate the regenerated energy. Shunt regulators are essentially a resistor placed in parallel with the DC bus. The shunt regulator will "turn-on" at a certain voltage level (set below the drive over-voltage shutdown level) and discharge the regenerated electric energy in the form of heat.

The voltage rise on the power supply capacitors without a shunt regulator, can be calculated according to a simple energy balance equation. The amount of energy transferred to the power supply can be determined through:

$$E_i = E_f$$

Where:

E_i -initial energy
E_f -final energy

These energy terms can be broken down into the approximate mechanical and electrical terms - capacitive, kinetic, and potential energy. The energy equations for these individual components are as follows:

$$E_c = \frac{1}{2} C V_{nom}^2$$

Where:

E_c -energy stored in a capacitor (joules)
C -capacitance
V_{nom} -nominal bus voltage of the system

$$E_r = \frac{1}{2}J\omega^2$$

Where:

E_r	-kinetic (mechanical) energy of the load (joules)
J	-inertia of the load (kg-m^2)
ω	-angular velocity of the load (rads/s)

$$E_p = mgh$$

Where:

E_p	-potential mechanical energy (joules)
m	-mass of the load (kg)
g	-gravitational acceleration (9.81 m/s^2)
h	-vertical height of the load (meters)

During regeneration the kinetic and potential energy will be stored in the power supply's capacitor. To determine the final power supply voltage following a regenerative event, the following equation may be used for most requirements:

$$(E_c \cdot E_r \cdot E_p)_i = (E_c \cdot E_r \cdot E_p)_f$$

$$\frac{1}{2}CV_{nom}^2 + \frac{1}{2}J\omega_i^2 + mgh_i = \frac{1}{2}CV_f^2 + \frac{1}{2}J\omega_f^2 + mgh_f$$

Which simplifies to:

$$V_f = \sqrt{V_{nom}^2 + \frac{J}{C}(\omega_i^2 - \omega_f^2) + \frac{2mg(h_i - h_f)}{C}}$$

The V_f calculated must be below the power supply capacitance voltage rating and the drive over voltage limit. If this is not the case, a shunt regulator is necessary. A shunt regulator is sized in the same way as a motor or drive, i.e. continuous and RMS power dissipation must be determined. The power dissipation requirements can be determined from the application move profile (see Figure 2.13).

ADVANCED Motion Controls offers a variety of shunt regulators for servo drives. When choosing a shunt regulator, select one with a shunt voltage that is greater than the DC bus voltage of the application but less than the over voltage shutdown of the drive. Verify the need

for a shunt regulator by operating the servo drive under the worst-case braking and deceleration conditions. If the drive shuts off due to over-voltage, a shunt regulator is necessary.

Continuous Regeneration

In the special case where an application requires continuous regeneration (more than a few seconds) then a shunt regulator may not be sufficient to dissipate the regenerative energy. Please contact *ADVANCED* Motion Controls for possible solutions to solve this kind of application. Some examples:

- Web tensioning device
- Electric vehicle rolling down a long hill
- Spinning mass with a very large inertia (grinding wheel, flywheel, centrifuge)
- Heavy lift gantry

Voltage Ripple

For the most part, *ADVANCED* Motion Controls AZ servo drives are unaffected by voltage ripple from the power supply. The current loop is fast enough to compensate for 60 Hz fluctuations in the bus voltage, and the components in the drive are robust enough to withstand all but the most extreme cases. Peak to peak voltage ripple as high as 25 V is acceptable.

There are some applications where the voltage ripple can cause unacceptable performance. This can become apparent where constant torque or force is critical or when the bus voltage is pulled low during high speed and high current applications. If necessary, the voltage ripple from the power supply can be reduced, either by switching from single phase AC to three phase AC, or by increasing the capacitance of the power supply.

The voltage ripple for a system can be estimated using the equation:

$$V_R = \frac{I_{PS}}{C_{PS}} F_f$$

Where:

V_R	-voltage ripple
C_{PS}	-power supply capacitance
I_{PS}	-power supply output current
F_f	-frequency factor (1/hertz)

The power supply capacitance can be estimated by rearranging the above equation to solve for the capacitance as:

$$C_{PS} = \frac{I_{PS}}{V_R} F_f$$

The frequency factor can determined from:

$$F_f = \frac{0.42}{f}$$

where f is the AC line frequency in hertz. Note that for half wave rectified power supplies, f = f/2.

The power supply output current, if unknown, can be estimated by using information from the output side of the servo drive as given below:

$$I_{PS} = \frac{V_M \cdot I_M}{V_{PS} \cdot (0.98)}$$

Where:

I_M	-current through the motor
V_{PS}	-nominal power supply voltage
V_M	-motor voltage (see "Motor Current and Voltage" on page 16)

2.8.3 Environment

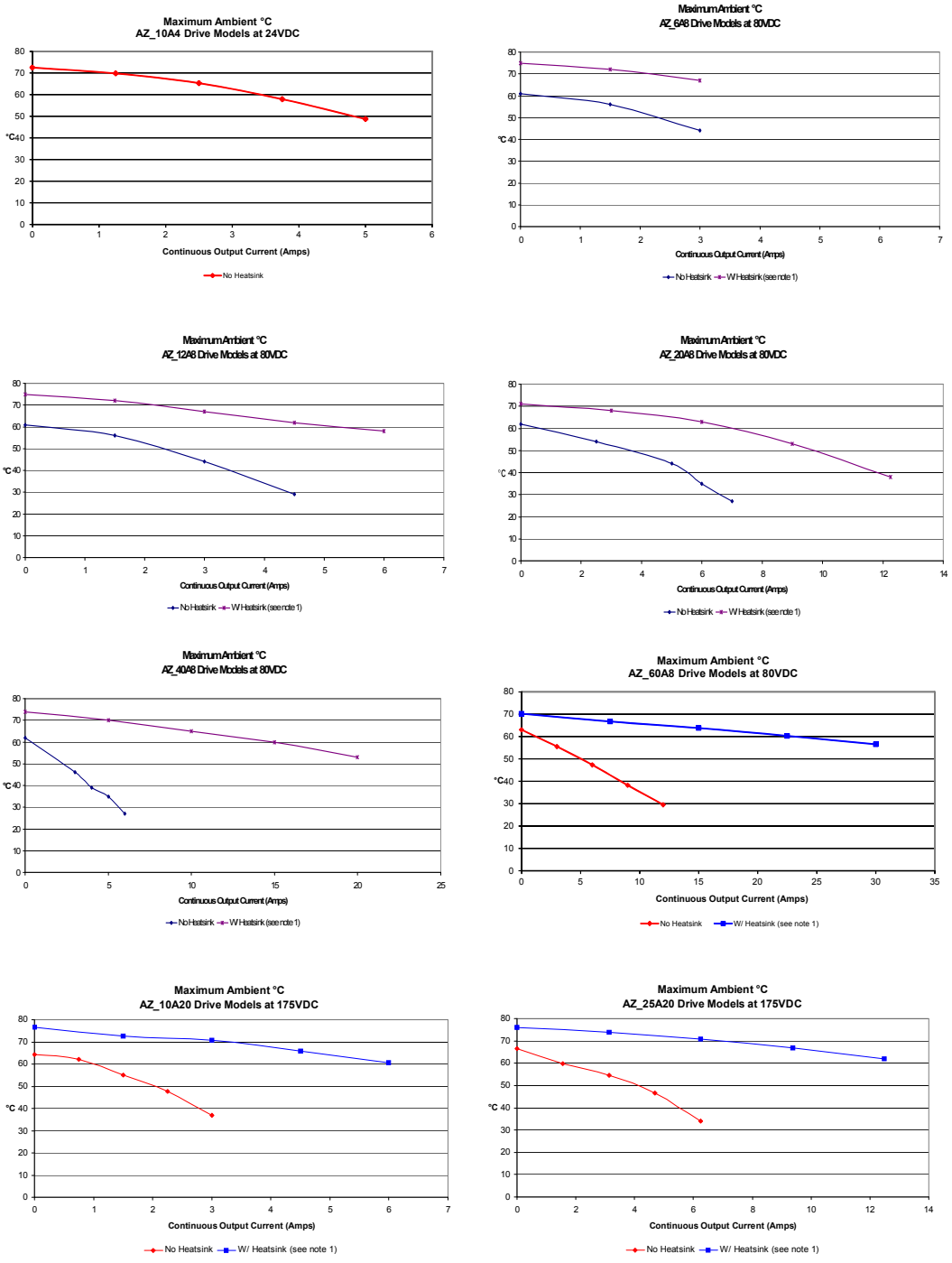
To ensure proper operation of an AZ servo drive, it is important to evaluate the operating environment prior to installing the drive.

TABLE 2.8 Environmental Specifications

Environmental Specifications	
Parameter	**Description**
Ambient Temperature Range	See Figure 2.17
Baseplate Temperature Range	See drive datasheet
Humidity	90%, non-condensing
Mechanical Shock	10g, 11ms, Half-sine
Vibration	2 - 2000 Hz @ 2.5g
Altitude	0-3000m

Ambient Temperature Range and Thermal Data AZ drives contain a built-in over-temperature disabling feature if the baseplate temperature rises above a certain value. For a specific continuous output current, the graphs below specify an upper limit to the ambient temperature range AZ drives can operate within while keeping the baseplate temperature below the over-temperature value. It is recommended to mount the baseplate of the AZ drive to a heatsink for best thermal management results. For mounting instructions and diagrams see "Mounting" on page 34.

FIGURE 2.17 AZ Ambient Temperature Ranges



3. The heatsink used in the above tests is a 15" x 22" x 0.65" aluminum plate.

Shock/Vibrations While AZ drives are designed to withstand a high degree of mechanical shock and vibration, too much physical abuse can cause erratic behavior, or cause the drive to cease operation entirely. Be sure the drive is securely mounted in the system to reduce the shock and vibration the drive will be exposed to. The best way to secure the drive against mechanical vibration is to use screws to mount the AZ drive against its baseplate. For information on mounting options and procedures, see "Mounting" on page 34.

Caution

Care should be taken to ensure the drive is securely mounted in a location where no moving parts will come in contact with the drive.

3 Integration in the Servo System

This chapter will give various details on incorporating an AZ servo drive into a system, such as how to design the PCB traces on an interface board, how to properly ground both the AZ drive along with the entire system, and how to properly connect motor wires, power supply wires, feedback wires, and inputs into the AZ drive.

3.1 LVD Requirements

The servo drives covered in the LVD Reference report were investigated as components intended to be installed in complete systems that meet the requirements of the Machinery Directive. In order for these units to be acceptable in the end users' equipment, the following conditions of acceptability must be met.

1. European approved overload and current protection must be provided for the motors as specified in section 7.2 and 7.3 of EN60204.1.
2. A disconnect switch shall be installed in the final system as specified in section 5.3 of EN60204.1.
3. All drives that do not have a grounding terminal must be installed in, and conductively connected to a grounded end use enclosure in order to comply with the accessibility requirements of section 6, and to establish grounding continuity for the system in accordance with section 8 of EN60204.1.
4. A disconnecting device that will prevent the unexpected start-up of a machine shall be provided if the machine could cause injury to persons. This device shall prevent the automatic restarting of the machine after any failure condition shuts the machine down.
5. European approved over current protective devices must be installed in line before the servo drive, these devices shall be installed and rated in accordance with the installation instructions (the installation instructions shall specify an over current rating value as low as possible, but taking into consideration inrush currents, etc.). Servo drives that incorporate their own primary fuses do not need to incorporate over protection in the end users' equipment.

These items should be included in your declaration of incorporation as well as the name and address of your company, description of the equipment, a statement that the servo drives must not be put into service until the machinery into which they are incorporated has been declared in conformity with the provisions of the Machinery Directive, and identification of the person signing.

3.2 CE-EMC Wiring Requirements

The following sections contain installation instructions necessary for meeting EMC requirements.

General

1. Shielded cables must be used for all interconnect cables to the drive and the shield of the cable must be grounded at the closest ground point with the least amount of resistance.
2. The drive's metal enclosure must be grounded to the closest ground point with the least amount of resistance.
3. The drive must be mounted in such a manner that the connectors and exposed printed circuit board are not accessible to be touched by personnel when the product is in operation. If this is unavoidable there must be clear instructions that the amplifier is not to be touched during operation. This is to avoid possible malfunction due to electrostatic discharge from personnel.

Analog Input Drives

4. A Fair Rite model 0443167251 round suppression core must be fitted to the low level signal interconnect cables to prevent pickup from external RF fields.

PWM Input Drives

5. A Fair Rite model 0443167251 round suppression core must be fitted to the PWM input cable to reduce electromagnetic emissions.

MOSFET Switching Drives

6. A Fair Rite model 0443167251 round suppression core must be fitted at the load cable connector to reduce electromagnetic emissions.
7. An appropriately rated Cosel TAC series AC power filter in combination with a Fair Rite model 5977002701 torroid (placed on the supply end of the filter) must be fitted to the AC supply to any MOSFET drive system in order to reduce conducted emissions fed back into the supply network.

IGBT Switching Drives

8. An appropriately rated Cosel TAC series AC power filter in combination with a Fair Rite model 0443167251 round suppression core (placed on the supply end of the filter) must be fitted to the AC supply to any IGBT drive system in order to reduce conducted emissions fed back into the supply network.
9. A Fair Rite model 0443164151 round suppression core and model 5977003801 torroid must be fitted at the load cable connector to reduce electromagnetic emissions.

Fitting of AC Power Filters

It is possible for noise generated by the machine to "leak" onto the main AC power, and then get distributed to nearby equipment. If this equipment is sensitive, it may be adversely affected by the noise. AC power filters can filter this noise and keep it from getting on the AC power signal.The above mentioned AC power filters should be mounted flat against the

enclosure of the product using the mounting lugs provided on the filter. Paint should be removed from the enclosure where the filter is fitted to ensure good metal to metal contact. The filter should be mounted as close to the point where the AC power filter enters the enclosure as possible. Also, the AC power cable on the load end of the filter should be routed far from the AC power cable on the supply end of the filter and all other cables and circuitry to minimize RF coupling.

3.2.1 Ferrite Suppression Core Set-up

If PWM switching noise couples onto the feedback signals or onto the signal ground, then a ferrite suppression core can be used to attenuate the noise. Take the motor leads and wrap them around the suppression core as many times as reasonable possible, usually 2-5 times. Make sure to strip back the cable shield and only wrap the motor wires. There will be two wires for single phased (brushed) motors and 3 wires for three phase (brushless) motors. Wrap the motor wires together as a group around the suppression core and leave the motor case ground wire out of the loop. The suppression core should be located as near to the drive as possible. TDK ZCAT series snap-on filters are recommended for reducing radiated emissions on all I/O cables.

3.2.2 Inductive Filter Cards

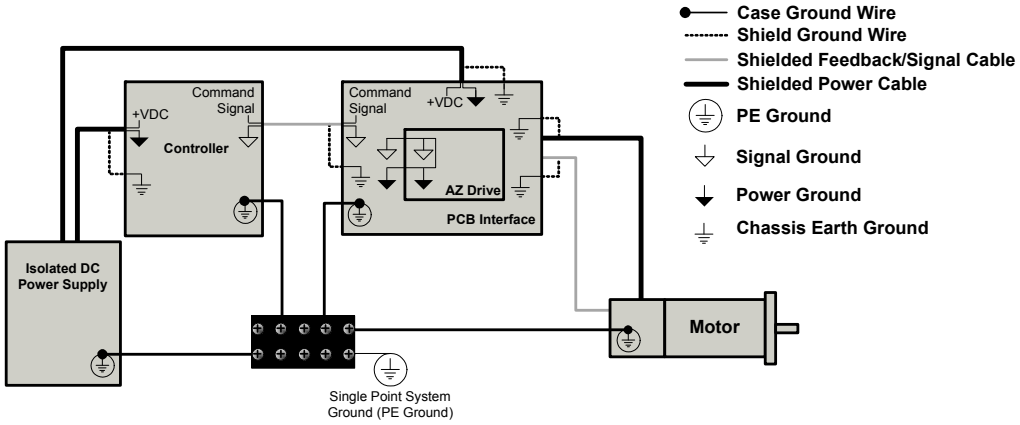
Inductive filter cards are added in series with the motor and are used to increase the load inductance in order to meet the minimum load inductance requirement of the drive. They also serve to counteract the effects of line capacitance found in long cable runs and in high voltage systems. These filter cards also have the added benefit of reducing the amount of PWM noise that couples onto the signal lines.

3.3 Grounding

In most servo systems all the case grounds should be connected to a single Protective Earth (PE) ground point in a "star" configuration. Grounding the case grounds at a central PE ground point reduces the chance for ground loops and helps to minimize high frequency voltage differentials between components. All ground wires must be of a heavy gauge and be as short as possible. The following should be securely grounded at the central PE grounding point:

- Motor chassis
- Controller chassis
- Power supply chassis
- PCB Interface chassis

FIGURE 3.1 System Grounding



Ground cable shield wires at the mounting card or PCB interface side to a chassis earth ground point.

The DC power ground and the input reference command signal ground are oftentimes at a different potential than chassis/PE ground. The signal ground of the controller must be connected to the signal ground of the AZ drive to avoid picking up noise due to the "floating" differential servo drive input. On all AZ drives, the DC power ground and the input command signal ground are referenced to each other internally. In systems using an isolated DC power supply, signal ground and/or power ground can be referenced to chassis ground. First decide if this is both appropriate and safe. If this is the case, they can be grounded at the central grounding point.

Grounding is important for safety. The grounding recommendations in this manual may not be appropriate for all applications and system machinery. It is the responsibility of the system designer to follow applicable regulations and guidelines as they apply to the specific servo system.

3.4 Wiring

Servo system wiring typically involves wiring a controller (digital or analog), a servo drive, a power supply, and a motor. Wiring these servo system components is fairly easy when a few simple rules are observed.

As with any high efficiency PWM servo drive, the possibility of noise and interference coupling through the cabling and wires can be harmful to overall system performance. Noise in the form of interfering signals can be coupled:

- Capacitively (electrostatic coupling) onto signal wires in the circuit (the effect is more serious for high impedance points).
- Magnetically to closed loops in the signal circuit (independent of impedance levels).
- Electromagnetically to signal wires acting as small antennas for electromagnetic radiation.
- From one part of the circuit to other parts through voltage drops on ground lines.

Experience shows that the main source of noise is the high DV/DT (typically about 1V/nanosecond) of the drive's output power stage. This PWM output can couple back to the signal lines through the output and input wires. The best methods to reduce this effect are to move signal and motor leads apart, add shielding, and use differential inputs at the drive. For extreme cases, use of an inductive filter card is recommended.

Unfortunately, low-frequency magnetic fields are not significantly reduced by metal enclosures. Typical sources are 50 or 60 Hz power transformers and low frequency current changes in the motor leads. Avoid large loop areas in signal, power-supply, and motor wires. Twisted pairs of wires are quite effective in reducing magnetic pick-up because the enclosed area is small, and the signals induced in successive twist cancel.

3.4.1 Wire Gauge

As the wire diameter decreases, the impedance increases. Higher impedance wire will broadcast more noise than lower impedance wire. Therefore, when selecting the wire gauge for the motor power wires, power supply wires, and ground wires, it is better to err on the side of being too thick rather than too thin. This recommendation becomes more critical as the cable length increases.

3.4.2 Motor Wires

The motor power wires supply power from the drive to the motor. Use of a twisted, shielded pair for the motor power cables is recommended to reduce the amount of noise coupling to sensitive components.

- For a brushed motor or voice coil, twist the two motor wires together as a group.
- For a brushless motor, twist all three motor wires together as a group.

Ground the motor power cable shield at one end only to the mounting card or PCB interface chassis ground. The motor power leads should be bundled and shielded in their own cable and kept separate from feedback signal wires.

DO NOT use wire shield to carry motor current or power!

3.4.3 Power Supply Wires

The PWM current spikes generated by the power output-stage are supplied by the internal power supply capacitors. In order to keep the current ripple on these capacitors to an acceptable level it is necessary to use heavy power supply leads and keep them as short as possible. Reduce the inductance of the power leads by twisting them. Ground the power supply cable shield at one end only to the mounting card or PCB interface chassis ground.

When multiple drives are installed in a single application, precaution regarding ground loops must be taken. Whenever there are two or more possible current paths to a ground

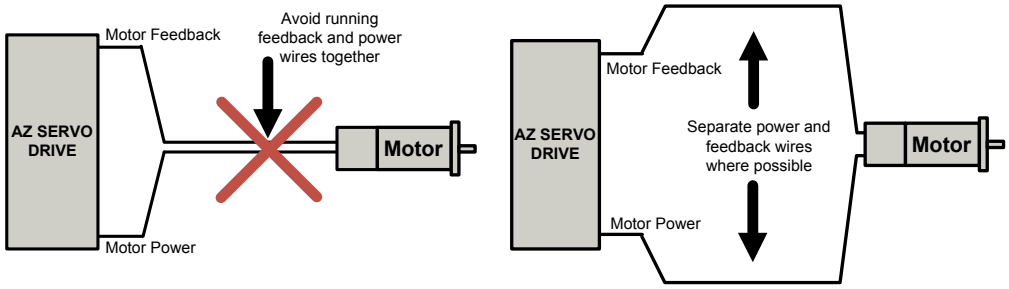
connection, damage can occur or noise can be introduced in the system. The following rules apply to all multiple axis installations, regardless of the number of power supplies used:

1. Run separate power supply leads to each drive directly from the power supply filter capacitor.
2. Never "daisy-chain" any power or DC common connections. Use a "star"-connection instead.

3.4.4 Feedback Wires

Use of a twisted, shielded pair for the feedback wires is recommended. Ground the shield at one end only to the mounting card or PCB interface chassis ground. Route cables and/or wires to minimize their length and exposure to noise sources. The motor power wires are a major source of noise, and the motor feedback wires are susceptible to receiving noise. This is why it is never a good idea to route the motor power wires with the motor feedback wires, even if they are shielded. Although both of these cables originate at the drive and terminate at the motor, try to find separate paths that maintain distance between the two. A rule of thumb for the minimum distance between these wires is 10cm for every 10m of cable length.

FIGURE 3.2 Feedback Wiring



3.4.5 Input Reference Wires

Use of a twisted, shielded pair for the input reference wires is recommended. Connect the reference source "+" to "+REF IN", and the reference source "-" (or common) to "-REF IN". Connect the shield to the mounting card or PCB interface chassis ground. The servo drive's reference input circuit will attenuate the common mode voltage between signal source and drive power grounds. In case of a single-ended reference signal, connect the command signal to +REF IN and connect the command return and -REF IN to signal ground.

Note

If you are using an AZ drive to replace an *ADVANCED* Motion Controls' panel mount drive, the same command input to the ±REF IN input pins on the AZ drive will result in the motor spinning in the opposite direction as with the panel mount drive. This can be changed by swapping the command input wiring (+REF IN to Pin 3 (Pin 2 for AZ_10A4 models) instead of Pin 1, and -REF IN to Pin 1 instead of Pin 3).

Long signal wires (10-15 feet and up) can also be a source of noise when driven from a typical OP-AMP output. Due to the inductance and capacitance of the wire the OP-AMP can oscillate. It is always recommended to set a fixed voltage at the controller and then check the signal at the drive with an oscilloscope to make sure that the signal is noise free.

3.5 Mounting

This section provides information on the different ways to mount an AZ drive to a PCB board.

3.5.1 Mounting Cards

Mounting cards are available to interface directly with certain AZ servo drives.

TABLE 3.1 Mounting Card Drive Compatibility

Mounting Card	Compatible Drive Models	Connector Type
MC1XAZ01	AZ_6A8, AZ_12A8, AZ_20A8, AZ_10A20, AZ_25A20	Vertical-Entry Quick-Disconnect
MC1XAZ01-HR	AZ_6A8, AZ_12A8, AZ_20A8, AZ_40A8, AZ_60A8‡, AZ_10A20, AZ_25A20	Side-Entry (Quick-Disconnect I/O, Fixed Screw Terminal Motor/Power)
MC1XAZ02	AZB10A4, AZBDC10A4, AZBE10A4, AZBH10A4, AZBD10A4	Side Entry Fixed Screw Terminal

‡Do not command more than 24A continuous current if using the MC1XAZ01-HR with the AZ_60A8 models

Pinouts, dimensions, and ordering information for the mounting cards are obtainable on the mounting card datasheets, available for download at www.a-m-c.com. The mounting cards are shipped with the following included connectors:

TABLE 3.2 MC1XAZ01 Included Quick-Disconnect Connectors

MC1XAZ01 Included Quick-Disconnect Connectors		
Description	Qty. Included	Manufacturer and Part Number
3-position 5.08mm spaced plug terminal	1	Phoenix Contact: 1757022
4-position 5.08mm spaced plug terminal	1	Phoenix Contact: 1757035
8-position 3.5mm spaced plug terminal	2	Phoenix Contact: 1840421

TABLE 3.3 MC1XAZ01-HR Included Quick-Disconnect Connectors

MC1XAZ01-HR Included Quick-Disconnect Connectors		
Description	Qty. Included	Manufacturer and Part Number
8-position 3.5mm spaced plug terminal	2	Phoenix Contact: 1863217

FIGURE 3.3 MC1XAZ01

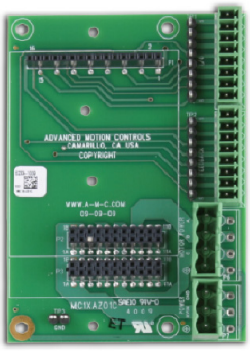


FIGURE 3.4 Mating Connectors

All four mating connectors shown are included with the MC1XAZ01.

Side-entry versions of the two 8-position connectors are included with the MC1XAZ01-HR.

FIGURE 3.5 MC1XAZ01-HR

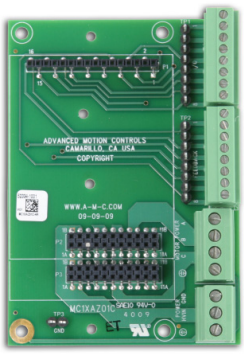
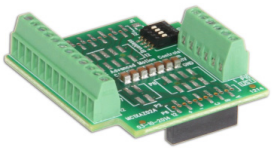
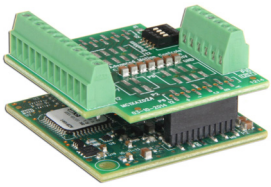


FIGURE 3.6 MC1XAZ02





The mounting cards can be secured to a panel, heatsink, or other surface with the use of standoffs or spacers. The following figures show some possible mounting configurations using AZ drives and the MC1XAZ01 and MC1XAZ01-HR mounting cards. Figure 3.7 below shows an AZ_20A8 drive attached to a MC1XAZ01 mounted to a panel. Four threaded spacers are used to secure the mounting card to the panel. Note that when using an MC1XAZ01 with the included mating connectors, the wire connections to the mounting card will be from the top.

FIGURE 3.7 **AZ_20A8 attached to MC1XAZ01 mounted on panel (shown with mating connectors installed)**

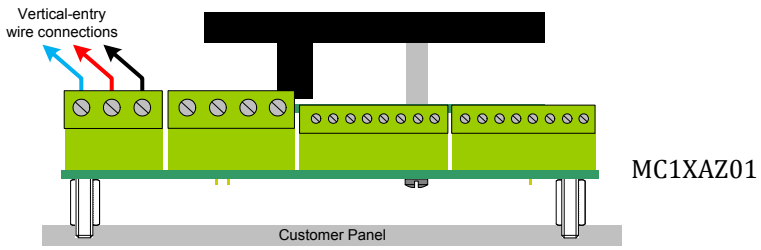
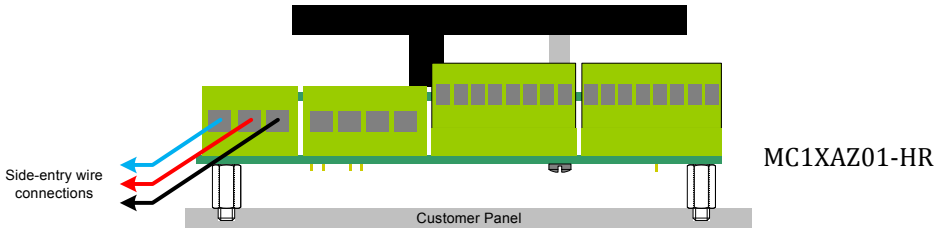


Figure 3.8 below shows an AZ_40A8 drive attached to an MC1XAZ01-HR mounted to a panel. Four threaded spacers are used to secure the mounting card to the panel. Note that when using an MC1XAZ01-HR with the included mating connectors, the wire connections to the mounting card will be from the side.

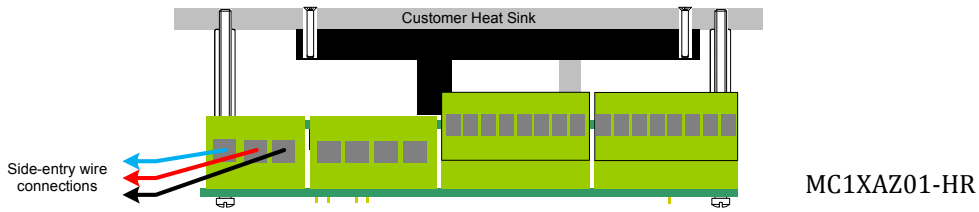
FIGURE 3.8 **AZ_40A8 attached to MC1XAZ01-HR mounted on panel (shown with mating connectors installed)**



The MC1XAZ01-HR is useful in system setups for both AZ_40A8 and lower current AZ drives where wire connections from above the mounting card would be difficult due to enclosed spaces or certain mounting configurations (such as Figure 3.9 below).

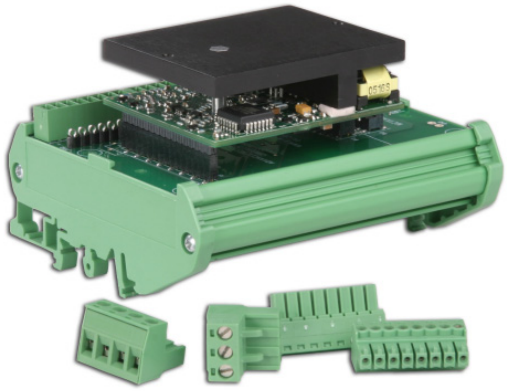
Figure 3.9 below shows an AZ_40A8 drive attached to an MC1XAZ01-HR. The drive is secured by two screws through its baseplate to an external heat sink, and the mounting card is secured with four threaded spacers to the external heat sink for additional stability.

FIGURE 3.9 **AZ_40A8 drive attached to MC1XAZ01-HR mounted to heat sink (shown with mating connectors installed)**



The mounting cards are also designed for easy mounting and installation on a standard DIN-rail tray, available from Phoenix Contact (www.phoenixcontact.com, part number 2952020/UM72/10.16/GN6021). Figure 3.10 below shows an AZ_20A8 drive mounted on a MC1XAZ01 that is installed on a DIN tray.

FIGURE 3.10 **MC1XAZ01 and AZ_20A8 Drive Mounted on MC1XAZ01 and Phoenix Contact DIN Tray (mating connectors shown are included with MC1XAZ01, DIN tray shown for reference only, available from Phoenix Contact)**



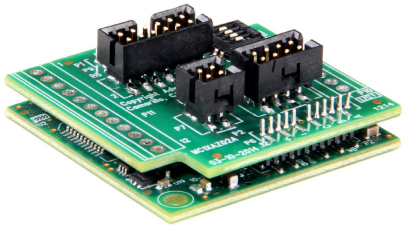
In addition, users may design their own mounting card to mate with an AZ servo drive. For more information on designing an AZ compatible PCB interface card, see "PCB Design" on page 40.

AZB_10A4IC The AZB_10A4IC models are a servo drive and inteface mounting card soldered together to provide quick access to all drive features. All drive I/O, supply power, and motor power pins are accessible via connectors on the interface card. Mating connectors for the interface card connections are included and listed below in Table 3.4.

TABLE 3.4 AZB_10A4IC Included Quick-Disconnect Connectors

MC1XAZ01 Included Quick-Disconnect Connectors		
Description	**Qty. Included**	**Manufacturer and Part Number**
12-port 2.0mm spaced plug terminal	1	Molex: P/N 51110-1260 (housing); 50394-8051 (crimp pins)
4-port 2.0mm spaced plug terminal	1	Molex: P/N 51110-0460 (housing); 50394-8051 (crimp pins)
8-port 2.0mm spaced plug terminal	1	Molex: P/N 51110-0860 (housing); 50394-8051 (crimp pins)

FIGURE 3.11 **AZB_10A4IC**

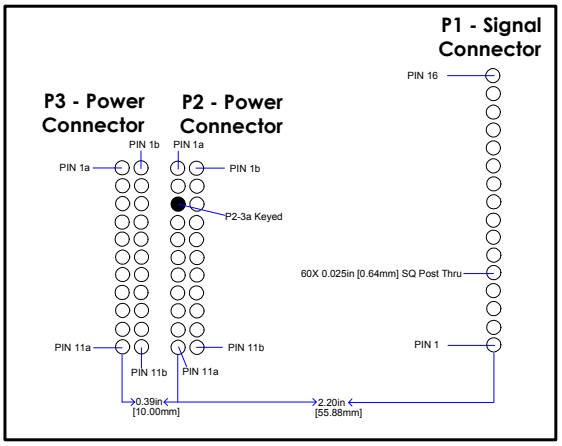


3.5.2 PCB Mounting Options

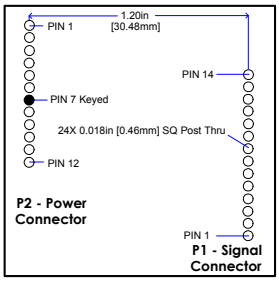
AZ servo drives can be directly integrated onto a PCB, either by mounting the board on socket connectors or by actually soldering the AZ drive to the board. Except for the AZ_10A4 models, AZ drives are designed with a common pin layout throughout the entire drive family, providing the user with the option of designing only one mounting card or PCB interface that is compatible with the different power levels. For an application that may have different versions with higher or lower power requirements, the same mounting card or PCB interface can be used for each application version with the appropriate AZ drive.

FIGURE 3.12 AZ Drives PCB Footprint (not to scale)

80V and 200V Drive Models



40V Drive Models



For the 80V and 200V drive versions, AZ_6A8 and AZ_12A8 drive models connect to P1 and the "A" row of P2, while AZ_20A8 and AZ_10A20 drives connect to P1 and both rows of P2. AZ_40A8, AZ_60A8, and AZ_25A20 models connect to P1, P2, and P3.

Notice

The MC1XAZ01 and MC1XAZ01-HR mounting cards contain a "keyed" socket connector on P2 to coincide with the "keyed" power header on AZ drives. It is recommended to include this feature on user designed mounting cards to avoid connecting the drive with the wrong orientation.

Mating Connectors AZ drives use square post male headers for signal and power pins that are designed for fast and easy removal from PCB-mount socket connectors, making this option particularly useful when prototyping. The socket mating connectors compatible with AZ drives are shown in the table below.

TABLE 3.5 AZ Drives Socket Mating Connectors

Connector	Pins	Manufacturer and Part Number
Signal Connector - AZB10A4, AZBDC10A4	12	Samtec: RSM-112-02-L-S
Signal Connector - AZBE10A4, AZBH10A4, AZBD10A4	14	Samtec: RSM-114-02-L-S
Signal Connector - AZ_6A8, AZ_12A8, AZ_20A8, AZ_40A8, AZ_60A8, AZ_10A20, AZ_25A20	16	Samtec: BCS-116-L-S-PE
Power Connector - AZ_10A4	12	Samtec: RSM-112-02-L-S
Power Connector - AZ_6A8 and AZ_12A8	11	Samtec: BCS-111-L-S-PE
Power Connector - AZ_20A8, AZ_40A8*, AZ_60A8*, AZ_10A20, AZ_25A20*	22	Samtec: BCS-111-L-D-PE

*AZ_40A8, AZ_60A8, and AZ_25A20 drive models will require two BCS-111-L-D-PE mating connectors for the power connectors

Soldering

Soldering an AZ board directly to a PCB provides added support against mechanical shocks and vibration. It is recommended to solder AZ drives to a PCB following the industry standard for Acceptability of Electronic Assemblies IPC-A-610D. Use solder with no-clean flux. AZ drives can be soldered by any of the following methods:

- wave soldering
- hand soldering
- selective wave soldering

To clean the PCB and drive after soldering, it is recommended to gently apply isopropyl alcohol or a cleaning agent with a soft-bristled brush. Use care not to apply downward pressure, but rather lightly brush the PCB and drive. Do not immerse the drive in a cleaning agent.

Screw Mounting

For added stability and support, AZ drives can be mounted with screws in tandem with one of the options above. Figure 3.13 shows how AZ_20A8, AZ_40A8, AZ_60A8, AZ_10A20, and AZ_25A20 drives can be mounted to a mounting card using a spacer, and Figure 3.14 shows the mounting procedure for AZ_6A8 and AZ_12A8 drives. AZ_10A4 models feature two screw mounting locations on opposite corners of the PCB. See "Physical Dimensions" on page 64 and/or the specific drive's datasheet for exact screw locations and dimensions.

FIGURE 3.13 Screw Mount Diagram

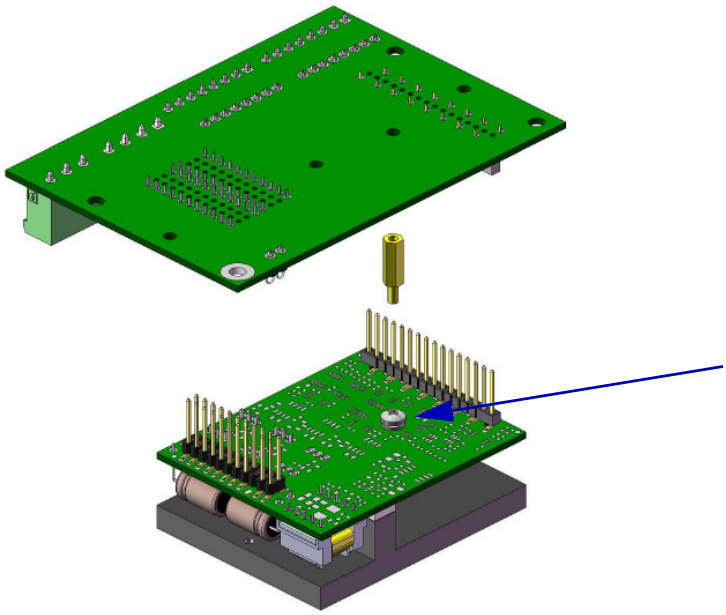
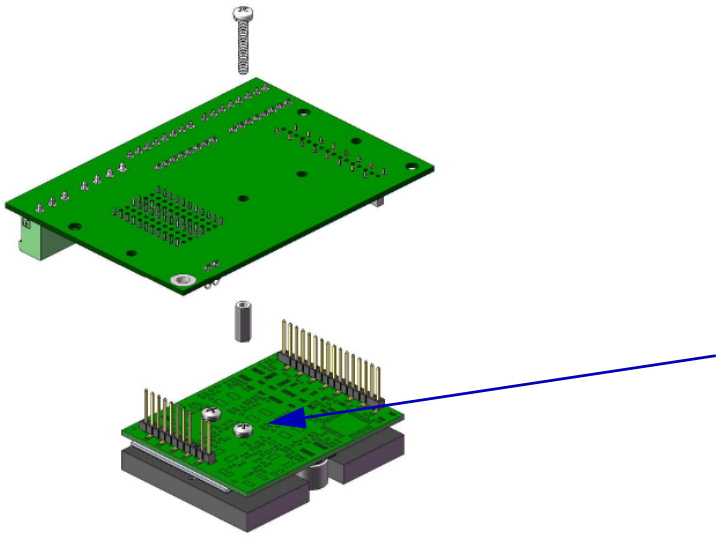

Remove drive mounting screw, and replace with spacer*. Use the removed drive mounting screw to secure mounting card to drive from the bottom of the mounting card through the spacer after drive has been inserted in mounting card socket connectors.
Drive Mounting Screw
*Spacer not included with AZ drive or mounting card. Spacer shown is standard 3/16" hex 4/40 thread, male/female, 7/16" length.

FIGURE 3.14 Screw Mount Diagram

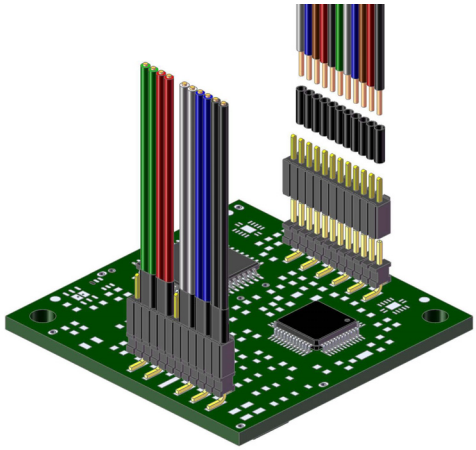

Remove drive mounting screw, and align spacer* over empty screw hole on drive PCB. Use a 4/40 thread, 1" screw to secure mounting card to drive from the bottom of the mounting card through the spacer after drive has been inserted in mounting card socket connectors.
Drive Mounting Screw
*Spacer not included with AZ drive or mounting card. Spacer shown is #4 clear, 7/16" length.

Larger model AZ drives can also be screw mounted through two 4/40 thread screw holes on either side of the AZ baseplate onto an external heatsink or other mounting plate for added stability and resiliency against mechanical vibration. Mounting to an external heatsink also provides better thermal management behavior than other mounting options. See "Ambient Temperature Range and Thermal Data" on page 25 for more info.

Direct Cabling

AZ_10A4 models can be directly cabled to using the recommended mating connector (Samtec P/N: SLM-112-01-L-S or SLM-114-01-L-S) as shown in Figure 3.15.

FIGURE 3.15 AZ_10A4 Direct Cabling



3.6 PCB Design

When designing a PCB board to interface with an AZ drive, there are some key features that must be kept in mind to ensure proper operation.

3.6.1 Trace Width and Routing

The proper design and implementation of the PCB traces on an interface card is essential in maximizing drive efficiency and noise reduction.

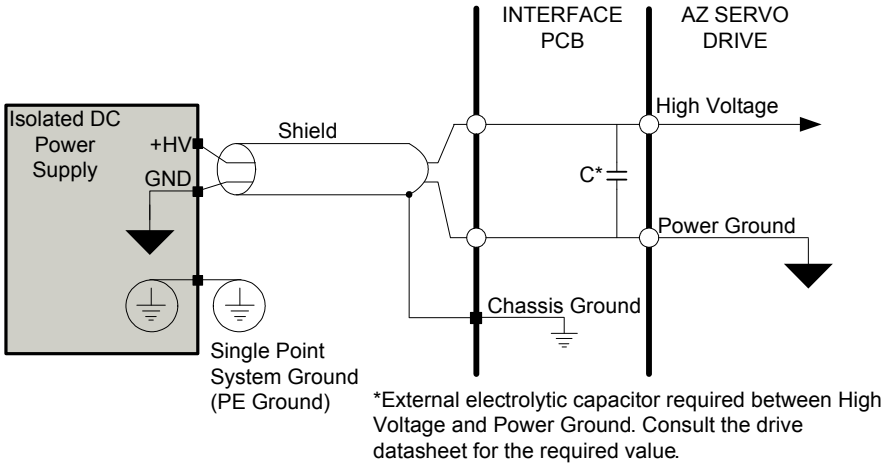
- **Keep high and low power signals separated -** Although AZ servo drives have an internal connection between power and signal ground, the traces emitting from the Power Connector, P2, carry high currents and voltages, while the traces emitting from the Signal Connector, P1, carry low currents voltages. Refrain from routing traces from P2 near traces from P1, and never route them in parallel. If power traces and signal traces need to cross, they should do so at right angles.
- **Keep high current traces short -** Traces carrying high current, such as the DC Power traces and Motor Signal traces, should be kept short and close together to minimize noise emissions. Also, keep DC Power traces separate from Motor Signal traces where possible.
- **Design for maximum values -** Adjacent traces can carry a voltage potential equal to the maximum DC power supply value, and carry current of both the AZ servo drive's peak and continuous current ratings. The trace width and copper plating thickness will need to take these maximum values into account. Also, be aware that AZ servo drive pin headers have a maximum current rating of 3 amps DC per pin. In order to achieve a higher overall peak current capability, some high current signals "share" a group of pins to spread the current between them. High current traces running to these pin groups should be inter-connected on the PCB board. Consult the drive's datasheet or the "Pinouts" section in "Products Covered" on page 7 for these pin groupings.

3.7 Interface Circuitry Examples

The following sections show examples of how an interface board could be designed to work with an AZ servo drive, and also contain general connection rules and instructions.

DC Power Input The diagram below shows how an AZ servo drive connects to an isolated DC Power Supply through a mounting card/interface PCB. Notice that the power supply wires are shielded, and that the power supply case is grounded at the single point system ground (PE Ground). The cable shield should be grounded at the mounting card or PCB interface side to chassis ground.

FIGURE 3.16 DC Power Input Wiring



Notice

Depending on the power capacity of the AZ drive model being used there may be multiple pins for DC Input Power connections. Refer to the datasheet of the specific model being used. The maximum current capacity per pin is 3A continuous.

Motor Power Output The diagram below shows how an AZ servo drive connects to a motor through a mounting card/interface PCB. Both brush-type and brushless motors should follow this general setup. Notice that the motor wires are shielded, and that the motor housing is grounded to the single point system ground (PE Ground). The cable shield should be grounded at the mounting card or PCB interface side to chassis ground.

FIGURE 3.17 Three Phase Motor Power Output Wiring

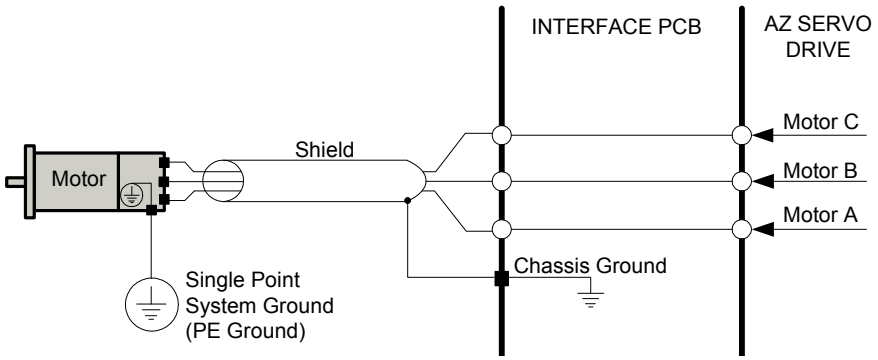
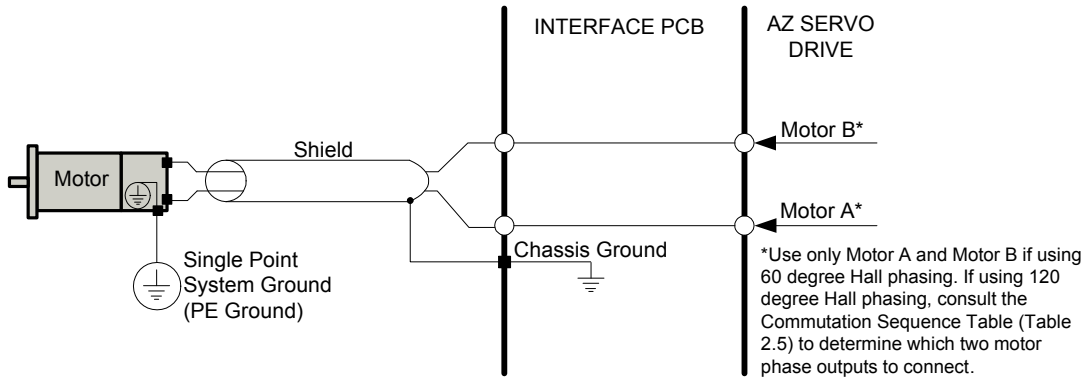


FIGURE 3.18 Single Phase Motor Power Output Wiring

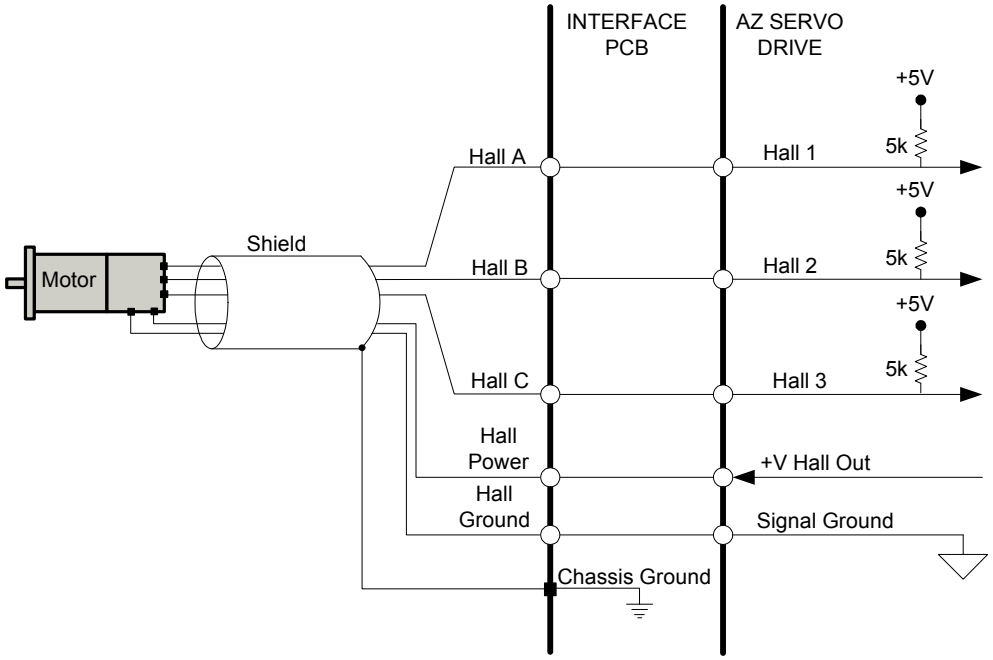

INTERFACE PCB
AZ SERVO DRIVE
Motor B*
Motor A*
Shield
Motor
Chassis Ground
Single Point System Ground (PE Ground)
*Use only Motor A and Motor B if using 60 degree Hall phasing. If using 120 degree Hall phasing, consult the Commutation Sequence Table (Table 2.5) to determine which two motor phase outputs to connect.

Depending on the power capacity of the AZ drive model being used there may be multiple pins for Motor Power connections. Refer to the datasheet of the specific model being used. The maximum current capacity per pin is 3A continuous.

If using relays or other means to disconnect the motor leads, be sure the drive is disabled before reconnecting the motor leads to the drive. Connecting the motor leads to the drive while it is enabled can generate extremely high voltage spikes which will damage the drive.

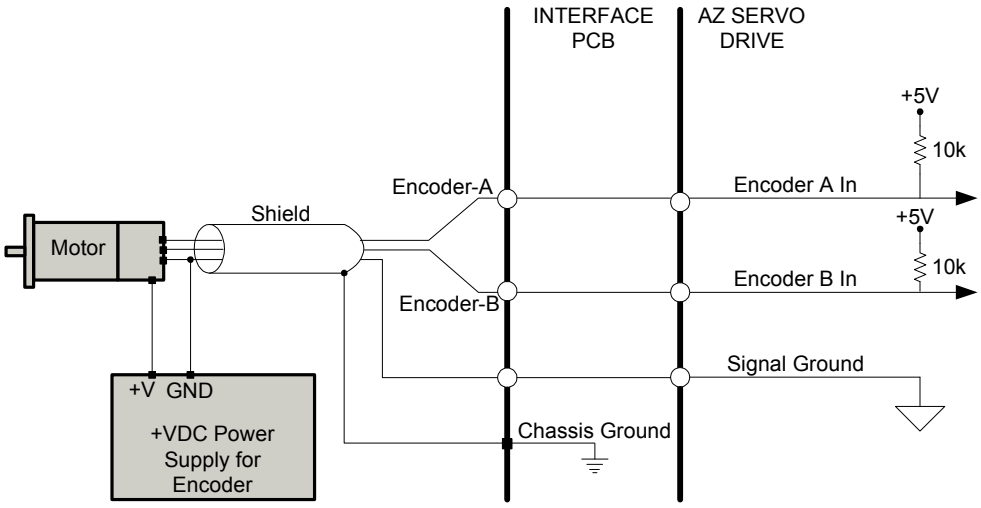
Hall Sensor Inputs AZ drives allow single-ended Hall Sensor inputs both for commutation, and in the special case of AZBH drives, for velocity feedback. AZ drives provide a +6V low power supply to power the Hall Sensors. Below is the recommended circuitry when designing a mounting card to interface with an AZ drive.

FIGURE 3.19 Hall Sensor Interface Wiring



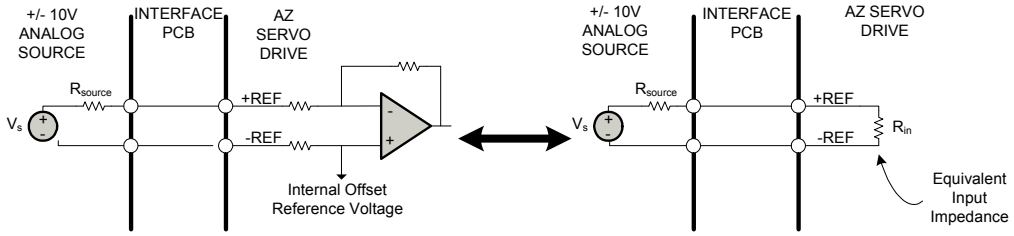
Encoder Inputs AZBE drives support single-ended incremental encoder inputs. The encoder must be powered by an external power supply. Check the motor and encoder specifications for the encoder voltage and current requirements. Below is the recommended circuitry when designing a mounting card to interface with an AZ drive.

FIGURE 3.20 Encoder Input Interface Wiring



±10V Analog Reference Input When using a ±10V analog signal for an input command, it is important to consider the output impedance of the analog source when interfacing to input circuitry. A poorly designed ±10V analog input interface can lead to undesired command signal attenuation. Figure 3.21 shows an external analog source connected to an analog input. The ideal voltage delivered to the input is $\mathbf{V_S}$. However, the voltage drop across $\mathbf{R_{source}}$ will reduce the signal being delivered to the drive input. This voltage drop is dependent on the value of $\mathbf{R_{source}}$ and the drive's input impedance.

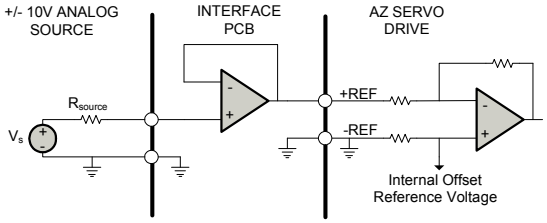
FIGURE 3.21 Analog Source and Drive Input



The drive's analog input can be simplified to a single impedance, $\mathbf{R_{in}}$, as shown in Figure 3.21. If the impedance of $\mathbf{R_{source}}$ is of the same magnitude or larger than $\mathbf{R_{in}}$, there will be a significant voltage drop across $\mathbf{R_{source}}$. Reduced values of $\mathbf{R_{source}}$ cause a lower voltage drop that increases signal integrity. In order to avoid a voltage drop of more than 5% between the source and the drive, it is recommended to use an $\mathbf{R_{source}}$ value of less than or equal to 2kohm.

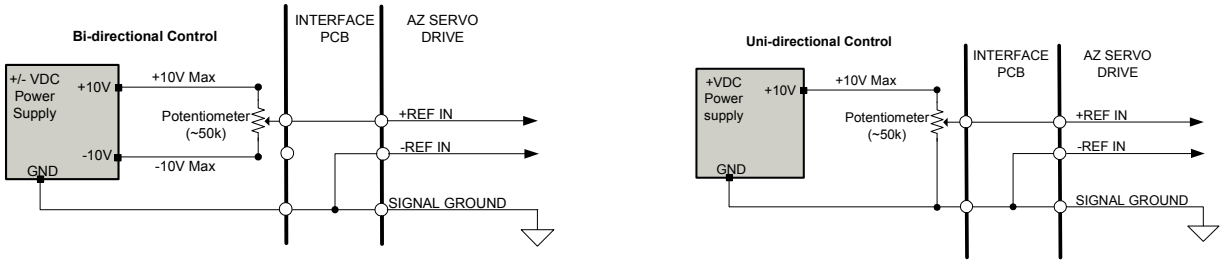
If there is a large output impedance from the analog source, it is recommended to use a buffer circuit between the analog source output and the drive input. A unity gain op-amp circuit as shown in Figure 3.22 will ensure low output impedance with minimal voltage drop.

FIGURE 3.22 Optimized Low Impedance Interface



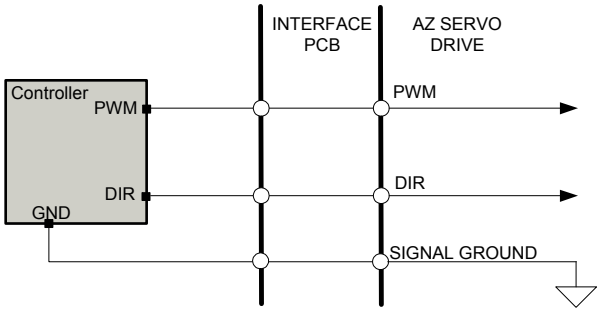
Potentiometer Input AZ servo drives can be commanded with the use of an external potentiometer and a DC supply by varying the DC supply voltage across the potentiometer.

FIGURE 3.23 Potentiometer Input



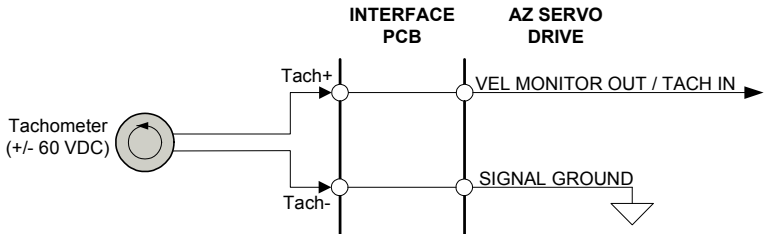
PWM and Direction Input For AZBDC drive models, the PWM and Direction inputs should be connected to the PWM and DIR input pins on the drive.

FIGURE 3.24 PWM and Direction Input Wiring



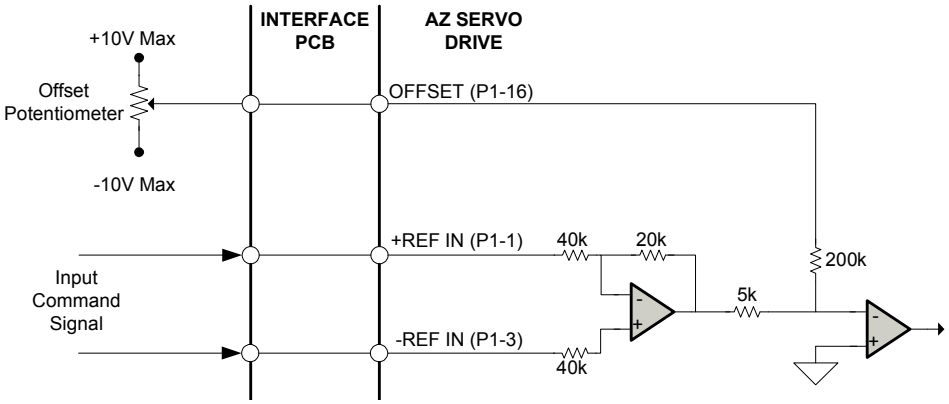
Tachometer Input For drive models that allow an external DC Tachometer for velocity control, the tachometer is connected between the Velocity Monitor Output / Tachometer Input pin (P1-15) and signal ground (either P1-7 or P1-2). The tachometer is limited to a feedback voltage range of ±60 VDC. The diagram below shows the recommended connection method.

FIGURE 3.25 DC Tachometer Input Wiring



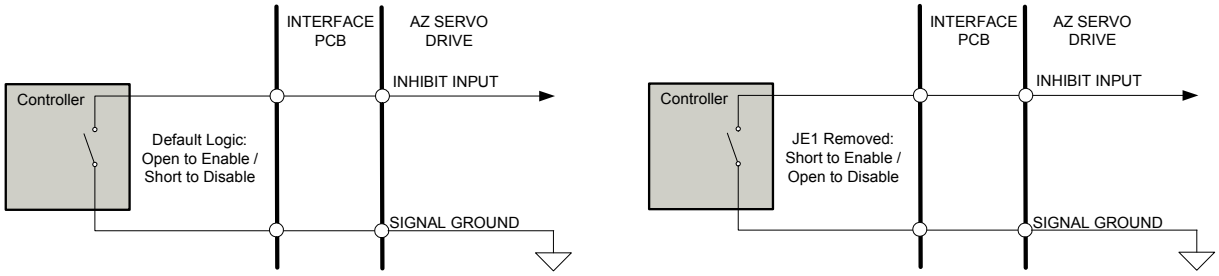
Offset Input For drive models that have an external offset input option, a potentiometer can be used in addition to the input command signal when an input offset adjustment is desired. The diagram below shows one possible connection method using a potentiometer for the offset input.

FIGURE 3.26 Offset Input Wiring



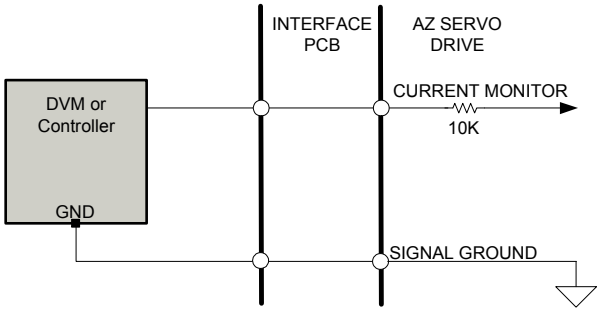
Inhibit Input AZ drives feature an Inhibit Input pin that is used to either enable or disable the drive. By default, the Inhibit Input pin should be left open to enable the drive, and brought to Signal Ground to disable the drive. This logic can be reversed if jumper JE1 is removed, however.

FIGURE 3.27 **Inhibit Input Wiring**



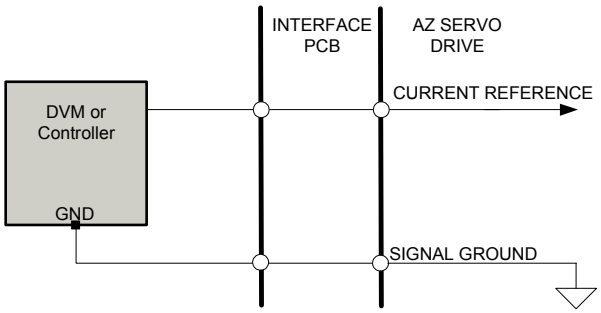
Current Monitor Output AZ drives feature a Current Monitor output that provides an analog voltage output signal that is proportional to the actual current output. The Current Monitor output should be measured relative to Signal Ground.

FIGURE 3.28 **Current Monitor Output Wiring**



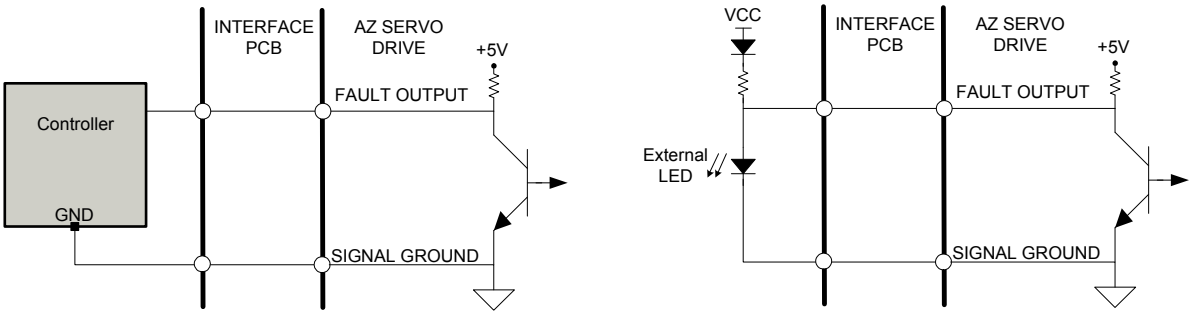
Current Reference Output Some AZ drives feature a Current Reference output that provides an analog voltage output signal that is proportional to the command signal to the internal current loop. The Current Reference output should be measured relative to Signal Ground.

FIGURE 3.29 **Current Reference Output Wiring**



Fault Output AZ drives feature a +5V TTL Fault output that will become high when the drive is subject to a fault condition (see "Fault Output" on page 49 for a list of fault conditions). The Fault output should be measured relative to Signal Ground. The Fault output can also be used with an external LED as shown in Figure 3.30.

FIGURE 3.30 **Fault Output Wiring**



4 Operation

This chapter will present a brief introduction on how to test and operate an AZ servo drive. Read through this entire section before attempting to test the drive or make any connections.

4.1 Getting Started

To begin operation with your AZ drive, be sure to read and understand the previous chapters in this manual as well as the drive datasheet. Be sure that all system specifications and requirements have been met, and become familiar with the capabilities and functions of the AZ drive. Also, be aware of the "Troubleshooting" section at the end of this manual for solutions to basic operation issues.

4.1.1 Input/Output Pin Functions

The family of AZ drives provides a number of various input and output pins for parameter observation and drive configuration options. Consult the drive datasheet to see which input/output pin functions are available for each drive.

Current Monitor Output The current monitor pin is available on all AZ drive models. Measured relative to signal ground, it provides an analog voltage output signal that is proportional to the actual current output. The scaling factor for each individual drive can be found on the drive datasheet.

Example Measurement

The current monitor pin on an AZ drive with a current monitor scaling factor of 4 A/V is measured to be 1.3V. This would mean the drive is outputting: (4 A/V)(1.3V) = **5.2A**.

Current Reference Output The current reference pin is available on 80V and 200V drive models. Measured relative to signal ground, it provides an analog voltage output signal that is proportional to the command signal to the internal current loop. When the drive output

reaches the maximum peak current value, the current reference pin will read 7.45V. The command to the internal current loop can be solved for by the following equation:

$$I_{\text{command}} = V_{\text{current ref}} \cdot \frac{I_{\text{peak}}}{7.45\,V}$$

Where:

$I_{command}$ -command current to the internal current loop
$V_{current\ ref}$ -measured voltage at current reference pin
I_{peak} -peak current value of AZ drive

Example Measurement

The current reference pin on an AZ drive with a peak current value of 12A is measured to be 2.63V. Following the above equation to solve for $I_{command}$, the command current to the internal current loop would be **4.24A**.

Fault Output The fault output is available on all AZ drive models. This pin provides a +5V TTL output that will become high when the drive is subject to one of the following fault conditions: inhibit, invalid Hall State, output short circuit, over voltage, over temperature, or power-up reset. This pin will remain low when the drive is enabled.

AZ drives automatically self-reset once all active fault conditions have been removed. For instance if the DC power supply rises above the over-voltage shutdown level of an AZ drive, the Fault Output will go high, and the drive will be disabled. Once the DC power supply level is returned to a value below the drive over-voltage shutdown level, the Fault Output will become low, and the drive will automatically become enabled.

Inhibit Input The inhibit input pin is available on all AZ drive models. This pin provides a +5V TTL input that allows a user to enable/disable the drive by either connecting this pin to ground or by applying a +5VDC voltage level to this pin, referenced to signal ground. By default, all AZ drives will be enabled if this pin is high, and disabled if this pin is low. This logic can be reversed, however, by removing the jumper JE1 from the drive PCB.

Low Power Supply Output The low power supply provides a +6 VDC, 30 mA output that can be used to power Hall Sensors on three phase drives (consult the motor datasheet to find out which feedback wire is the Hall Sensor power supply wire) or for other user requirements on single phase drives.

Notice

Do not use this +6V supply to power an encoder. An encoder will require a separate external power supply. Consult the encoder datasheet or specifications to determine the encoder voltage and current requirements. Typical values are +5VDC at 150mA.

Velocity Monitor Output The velocity monitor output pin is available on AZBE and AZBH drive models only. This pin provides an analog voltage output that is proportional to the actual motor speed.

- For AZBE drives in Encoder Velocity Mode, substitute the voltage value read at the velocity monitor pin, $V_{monitor}$, into the below equation to determine the motor RPM:

$$\text{Motor Velocity [RPM]} = \frac{V_{\text{monitor}} \cdot 22\frac{kHz}{V} \cdot 60}{\text{Number of encoder lines}}$$

- For AZBH drives in Hall Velocity Mode, substitute the voltage value read at the velocity monitor pin, $V_{monitor}$, into the below equation to determine the motor RPM:

$$\text{Motor Velocity [RPM]} = \frac{V_{\text{monitor}} \cdot 100\frac{Hz}{V} \cdot 120}{\text{Number of motor poles}}$$

Tachometer Input For AZBE and AZBH drive models, when the drive is set to Tachometer Velocity mode by DIP-switch setting, the Velocity Monitor Output pin is used as a DC Tachometer Input. The drive *must* be in Tachometer Velocity Mode in order to properly use the tachometer input. The maximum input allowed at the tachometer input pin is ±60 VDC.

When using a DC Tachometer in Tachometer Velocity mode, the velocity monitor output function is inactive.

4.1.2 Potentiometer Function Details

AZBE and AZBH drive models utilize two 0 to 50 kohm potentiometers for Loop Gain and Offset functions. Both potentiometers vary in resistance from 0 to 50 kohm, over 12 turns. An additional full turn that does not effect resistance is provided on either end, for a total of 14 turns. When the end of potentiometer travel is reached, it will click once for each additional turn.

TABLE 4.1 Potentiometer Function Details

Potentiometer	Description
Loop Gain Adjustment (located closest to corner of PCB)	This potentiometer must be set completely counter-clockwise in Current Mode. In Velocity or Duty Cycle Mode, this potentiometer adjusts the gain in the velocity forward position of the closed loop. Turning this potentiometer clockwise increases the gain. Start from the full counter-clockwise position, turn the potentiometer clockwise until the motor shaft oscillates, then back off one turn.
Offset (located furthest from corner of PCB)	This potentiometer is used to adjust a small amount of command offset in order to compensate for offsets that may be present in the servo system. Turning this potentiometer clockwise adjusts the offset in a negative direction relative to the +Ref input command. Before offset adjustments are made, the reference inputs must be grounded or commanded to 0 volts.

4.2 Initial Setup

Carefully follow the grounding and wiring instructions in the previous chapters to make sure your system is safely and properly set up. For initial testing purposes, it is not necessary to use a controller to provide a command input, or to have any load attached to the motor. The items required will be:

- AZ Servo Drive attached to Mounting Card or PCB Interface
- Motor
- DC Power Supply for supplying power to system
- Digital Multimeter (or ohmmeter and voltmeter)

4.2.1 Current (Torque) Mode Test

Initially, the AZ drive should be placed in Current (Torque) Mode. By default, all AZ drives are shipped already set for Current (Torque) Mode. However, AZBE and AZBH drives have the option of using DIP switches to configure the drive for other modes. If using an AZBE or AZBH drive model, check the DIP switch configuration to be certain the drive is in Current (Torque) Mode. Mode configuration tables can be found on the drive datasheet.

Connections Test Before applying power to the drive, connect the AZ drive to the mounting card or PCB interface, using any of the mounting options from "Mounting" on page 34. Using an ohmmeter or digital multimeter, test the connections between the mounting card or PCB interface headers and the AZ drive pins. Check for any shorts or open circuits. At this point, also check the ground connection of the whole system (AZ drive, mounting card, Motor). All these elements should have their case or chassis connected to a central grounding point in a "star" configuration. For review, see "Grounding" on page 30.

Power Supply

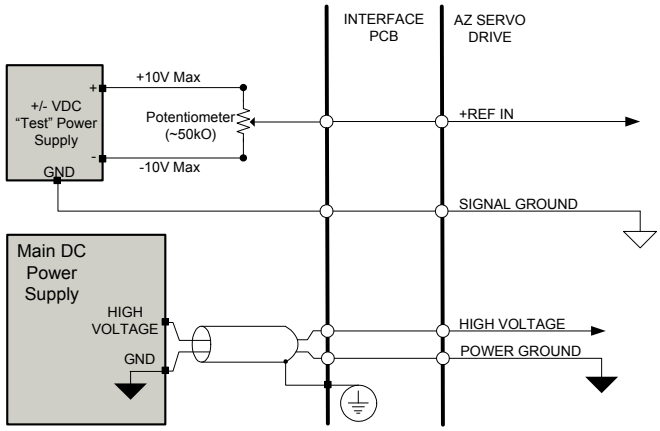
1. Before wiring the DC power supply to the mounting card and AZ drive, use a voltmeter or digital multimeter to make sure the DC voltage level is within specifications.
2. Do not turn on the DC power supply yet. Connect the DC power supply wires to the mounting card or PCB interface. Do not connect directly to the AZ drive header pins. Be sure the high voltage and ground connections do not get reversed, as this will damage the drive.
3. Turn on the DC power supply. Monitor the DC voltage on the mounting card test points or PCB interface to be sure the voltage level is within specifications. Once certain that power is being properly applied to the AZ drive, turn the DC power supply off.

Input Command Wiring Follow the instructions below to properly wire the input command of the AZ drive, but do not apply any power or input signal yet.

- For drives that use ±10 V analog input, one method of testing the functionality of the AZ drive within the system is by using an external reference potentiometer (approximately 50 kΩ) as an input command signal. By applying a positive DC voltage (10V max) to one end of the potentiometer, and a negative DC voltage (10V max) to the other end of the potentiometer, a ± analog signal can be sent through the potentiometer's wiper into the +REF input pin on the mounting card or PCB interface (see drive datasheet or "Pinouts" on page 15 for pin labels). The voltages applied to the external reference potentiometer

should come from a "test" power supply that is different than the main DC power. This separate ±VDC "test" power supply should be referenced to the AZ drive signal ground.

FIGURE 4.1 Reference Input Potentiometer



- Without connecting the potentiometer wiper to the mounting card or PCB interface, apply the "test" ±VDC to the two sides of the potentiometer.
- Measure the wiper of the potentiometer with a voltmeter or digital multimeter, and verify that by turning the potentiometer in both directions, the full range of ±VDC is observable on the potentiometer wiper. This voltage will serve as a "test" command.
- Once the full range of ±VDC has been verified, turn the potentiometer so that approximately 0 VDC is observed on the potentiometer wiper, then turn off the "test" power supply.
- With no voltage command applied to the potentiometer, connect the wiper to the +REF IN input pin on the mounting card or PCB interface. Connect the "test" power supply ground or common to the AZ drive signal ground on the mounting card or PCB interface.

- For drives that use PWM and Direction input, a Function Generator should be set up to generate a simple +5V square wave at a frequency of 10-25 kHz. Connect the Function Generator signal to the PWM input pin on the AZ drive, (see drive datasheet or "Pinouts" on page 15 for pin labels) and the common to the signal ground pin on the AZ drive.

Hall Sensors

1. (For brushless motors) With the DC power supply still turned off, connect the Hall Sensors to the Hall input pins on the mounting card or PCB interface. Also, connect the +V HALL OUT +6V supply from the AZ drive to the Hall Power line (consult the motor datasheet to see which wires from the motor are the Hall Input lines and Hall Power line).

   (For brushed motors) If using 60-degree Hall phasing, leave all Hall input pins open. If using 120-degree Hall phasing, tie one of the Hall inputs to ground, and leave the other two open.
2. Turn on the DC power supply to the system.
3. Use a digital multimeter or voltmeter, to monitor the Fault Output pin (see "Fault Output" on page 49 for more information).
4. Manually rotate the motor shaft by hand a few revolutions. If all the Hall Sensors are functioning properly, the Fault Output signal should stay low. If the Fault Output signal

goes high, this could indicate either a short or bad connection in the Hall Sensor wires, or an invalid commutation state. See "Hall Sensors" on page 10 for information on Hall commutation.

5. Once verified, turn off the DC power supply.

Motor With the DC power supply still turned off, connect the motor wires to the appropriate motor output pins on the mounting card or PCB interface.

- For three phase (brushless) motors, there will be three wires to connect. For now, connect the wires in any order to the motor output pins on the mounting card or PCB interface. These may need to be changed later in order to properly commutate the motor.
- For single phase (brushed) motors, there will be two wires to connect. If using 60-degree Hall phasing, connect the wires to motor output phases A and B in any order. If using 120-degree Hall phasing, then the proper motor output phases will depend on the Hall commutation state. See "Using a Single Phase Motor" on page 11 for more information.

Applying a Command (Analog Input) At this stage, everything that is needed to test operation should be connected to the AZ drive through the mounting card or PCB interface, all the elements should be properly grounded in a central point location, and no power or input command should be applied to any element in the system.

Once certain that all these steps have been safely and properly followed, turn on the main DC power supply. Use a voltmeter or digital multimeter to once again check the DC power supply level.

Analog Input Drives

1. Turn on the "test" power supply connected to the external potentiometer.
2. Slowly turn the potentiometer in one direction while observing the motor shaft.

Only make very slight adjustments to the reference potentiometer to avoid causing damage to the motor. Since the drive is in Current (Torque) Mode and there is no load on the motor shaft, even a small potentiometer adjustment can create high speeds at the motor shaft. Exercise caution when adjusting the potentiometer.

- For single phase motors, this should cause the motor shaft to energize in one direction. Slowly turning the potentiometer further in that same direction, and also in the opposite direction should cause the motor shaft to move smoothly in response to the input.
- For three phase motors, the three motor wires may have to be changed in order to properly commutate the motor. There are six different ways that the three motor wires can be attached to the mounting card or PCB interface. All six will have to be tested in order to find the right commutation.

Before removing the motor wires, turn off both the main DC power supply and the "test" power supply. Never remove or make any connections to the drive while power is applied!

The proper combination of motor wires will yield smooth motion and identical speeds in both directions. Improper combinations will cause jerky motion, slow movement in one

direction, and/or audible noise. Once the proper combination has been found, turning the potentiometer slowly in both directions should cause the motor shaft to rotate appropriately in response to the input.

PWM Input Drives

1. Turn on the function generator to apply the PWM signal to the PWM IN pin.
2. Monitor the Function Generator PWM signal on an oscilloscope. Be sure to keep the PWM frequency within the 10-25 kHz range. By varying the duty cycle of the PWM input signal, the motor shaft should rotate in response to the input.

- For single phase motors, this should cause the motor shaft to energize in one direction. Slowly varying the PWM duty cycle should cause the motor shaft to move smoothly in response to the input.
- For three phase motors, the three motor wires may have to be changed in order to properly commutate the motor. There are six different ways that the three motor wires can be attached to the mounting card or PCB interface. All six will have to be tested in order to find the right commutation.

Before removing the motor wires, turn off both the main DC power supply and the Function Generator. Never remove or make any connections to the drive while power is applied!

The proper combination of motor wires will yield smooth motion and identical speeds in both directions. Improper combinations will cause jerky motion, slow movement in one direction, and/or audible noise. Once the proper combination has been found, varying the duty cycle should cause the motor shaft to rotate appropriately in response to the input.

Motor Direction For brushless motors, if it is desired to change the motor direction for a given command input, interchange Hall 1 and Hall 3, then Motor A and Motor B.

4.3 Tuning Procedure

The standard tuning values used in *ADVANCED* Motion Controls AZ servo drives are conservative and work well in over 90% of applications. However some applications and some motors require more complete current loop tuning to achieve the desired performance. The following are indications that additional current loop tuning is necessary:

- Motor rapidly overheats even at low current
- Drive rapidly overheats even at low current
- Vibration sound comes from the drive or motor
- The motor has a high inductance (+10mH)
- The motor has a low inductance (near minimum rating of the drive)
- Slow system response times
- Excessive torque ripple
- Difficulty tuning position or velocity loops
- Electrical noise problems

- High power supply voltage (power supply is significantly higher than the motor voltage rating or near the drive's upper voltage limit)
- Low power supply voltage (power supply voltage is near the drive's lower voltage limit)

The above indicators are subjective and suggest that the current loop may need to be tuned. These can also be signs of other problems not related to current loop tuning.

The resistors and capacitors shown under the current control block on the datasheet block diagram determine the frequency response of the current loop. It is important to tune the current loop appropriately for the motor inductance and resistance, as well as the bus voltage to obtain optimum performance. The loop gain and integrator capacitance of the current loop must both be adjusted for the tuning to be complete.

Improper current loop tuning may result in permanent drive and/or motor damage regardless of drive current limits.

Since most *ADVANCED* Motion Controls servo drives close the current loop internally, poor current loop tuning cannot be corrected with tuning from an external controller. Only after the current loop tuning is complete can optimal performance be achieved with the velocity and position loops.

The general current loop tuning procedure for AZ drives follows these steps:

1. Determine if additional current loop tuning is necessary.
2. If tuning is necessary, then the current loop components must be changed.
   - Tune the current loop proportional gain.
   - Tune the current loop integral gain.
3. Once the current loop is tuned, then the velocity and/or position loops may be tuned as well if necessary.

Equipment Necessary for Tuning

- Function Generator
- Oscilloscope
- Current Probe or Resistor (high powered, low resistance)
- Soldering Iron

Current Loop Proportional Gain Adjustment

The Current Loop Gain should be adjusted with the motor uncoupled from the load, and the motor secured as sudden motor shaft movement may occur. To keep the motor from commutating during tuning, make sure the Hall Sensor wires are not connected to the drive at this point.

1. Use the DIP switches on Velocity Mode capable AZ drives to select Current Mode (other AZ drives are automatically in Current Mode).
2. Connect only the motor power leads to the drive. No other connections should be made at this point.

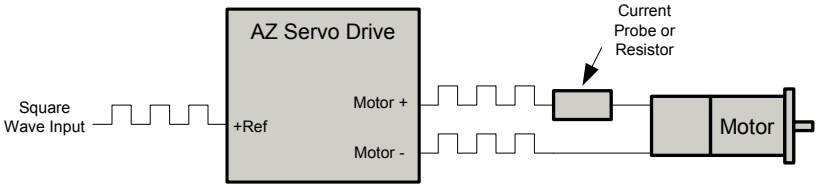
3. Using a function generator, apply a ±0.5 V, 50-100 Hz square wave reference signal to the input reference pins.
4. Short out the current loop integrator capacitor(s). Consult *ADVANCED* Motion Controls for capacitor location.

Notice

Any damage done to the drive while performing these modifications will void the product warranty.

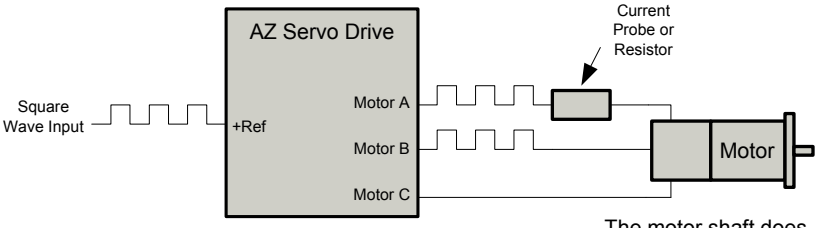
5. Apply power to the drive. Use a bus voltage that is approximate to the desired application voltage or the current loop compensation will not be optimized.
6. The drive should be enabled. Observe the motor current with an oscillscope by using a current probe or resistor in series with the motor (<10% of motor resistance). Depending on the motor type, the drives need to be set up differently to view the current loop response properly, as shown in the following figures.

FIGURE 4.2 Brushed Motors



Since the two motor wires are in series, the current through the wires is the same. The current probe can be attached to either wire with the same results. To keep the motor from turning during the tuning process the motor shaft must be locked.

FIGURE 4.3 Brushless Motors

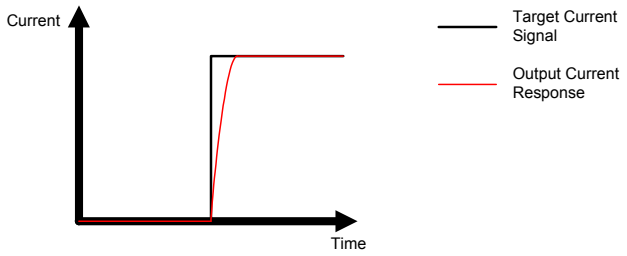


The current out of the drive can be forced to go through Motor A and Motor B by:
1) Disconnecting the Hall sensors from the drive
2) Jumper Hall 2 input to Signal Ground

The motor shaft does not need to be locked since the drive will not commutate without the Hall Sensors.

7. The drive output should follow the input command. The best response will be a critically damped output waveform, similar to what is shown in Figure 4.4.

FIGURE 4.4 Current Loop Response



8. If the drive output did not result in a proper square wave response, then the current loop gain resistors may need to be changed to optimize the response. See "Loop Tuning" on page 59 for more information.
9. When the proper response has been achieved, remove the input signal from the drive, and disconnect power.

Current Loop Integrator Adjustment

1. Enable the Current Loop Integrator by removing the jumper previously used to short it during the proportional gain adjustment, and start with the default capacitor.
2. Using a function generator, apply a ±0.5V, 50-100 Hz square wave reference signal.
3. Apply power to the drive. Use a bus voltage that is approximate to the desired application voltage or the current loop compensation will not be correct.
4. The drive should be enabled. Observe the motor current with an oscilloscope by using a current probe or resistor in series with the motor (<10% of motor resistance). The output should settle to a flat top with minimal current following error (difference between commanded current and actual current). There can be some overshoot, but it should be less than 10%.

Because the oscilloscope measurements are voltage representations of current, the commanded and actual currents will most likely have different current to voltage scalings and tolerances. Therefore, even with perfect current loop tuning, the two amplitudes (scope traces) may not line up as shown in Figure 4.4.

5. If the square wave output overshoots too much or is over-damped (sluggish), the current loop integrator capacitor will need to be changed to optimize the response. See "Loop Tuning" on page 59 for more information.

Duty Cycle or Velocity Loop Tuning

For AZBE and AZBH drives, the velocity loop proportional gain can be tuned for the system requirements by adjusting the Loop Gain potentiometer. These adjustments should initially be performed with the motor uncoupled from the mechanical load.

Configure the drive for the desired operation mode using the DIP Switchs (see the drive datasheet for the specific settings).

- Duty Cycle Loop - Compensating the duty cycle loop requires the least amount of effort. Turn the Loop Gain potentiometer clockwise until oscillation occurs, then back off one turn.

- Velocity Loop (Encoder, Halls, or Tachometer) - The velocity loop response is determined by the Loop Gain potentiometer as well. A larger resistance value (clockwise) results in a faster response. A smaller resistance value (counter-clockwise) results in a slower response. Adjust the Loop Gain potentiometer as necessary for the desired application performance.

If adjustments to the Loop Gain potentiometer do not result in the desired performance, the velocity loop integrator capacitor may need to be changed to optimize the response. See "Loop Tuning" on page 59 for more information.

A Loop Tuning

In general, *ADVANCED* Motion Controls AZ servo drives will not need to be further tuned. However, for applications requiring more precise tuning, the drive can be manually modified with resistors and capacitors as denoted in Table A.1 below.

It is recommended to contact *ADVANCED* Motion Controls to discuss application requirements and proper drive tuning prior to making any adjustments.

Notice

Any damage done to the drive while performing these modifications will void the product warranty.

Before attempting to change components on the board, see "Tuning Procedure" on page 54. Some general rules to follow when changing components are:

- A larger resistor value will increase the proportional gain, and therefore create a faster response time.
- Use non-polarized capacitors.
- A larger capacitor value will increase the integration time, and therefore create a slower response time.

A.1 Loop Tuning

Proper tuning will require careful observation of the loop response on a digital oscilloscope to find the optimal component values for the specific application.

The following are some helpful hints to make the loop tuning process easier:

- **Use a potentiometer to find the correct current loop gain value -** A potentiometer can be used to continuously adjust the gain resistance value during the tuning process. Install a potentiometer in place of the gain resistor. Adjust the potentiometer while viewing the current loop response on an oscilloscope. When the optimal response is achieved turn off the drive, remove the potentiometer, and measure the potentiometer resistance. Use the closest resistor value available. (Note: This method will not work if the optimal tuning value is beyond the range of the potentiometer).
- **If no potentiometer is available, progressively double the resistance value when tuning the current loop gain for faster results -** If the gain resistor needs to be

increased during the tuning process the fastest results are achieved by doubling the resistance from the last value tried. Use this method until overshoot is observed and then fine tune from there.

- **Safety**

Always remove power when changing components on the drive.

Float the oscilloscope and function generator grounds to avoid large ground currents.

Decouple the motor from the load to avoid being injured by sudden motor movements.

Table A.1 lists the different components that can be used for loop tuning. Consult the drive datasheet to see which options are available for a specific drive. Please contact *ADVANCED* Motion Controls Applications Engineering for assistance in determining the PCB location of the component options for the drive model in use.

TABLE A.1 Through-Hole Tuning Component

Component	Description
Current Loop Proportional Gain Resistor	Resistor that can be changed for more precise current loop tuning.
Current Loop Integrator Capacitor	Capacitor that can be changed for more precise current loop tuning.
Velocity Loop Integrator Capacitor	Capacitor that can be changed for more precise velocity loop tuning.

A.1.1 Procedure

Before changing any components on the PCB, follow the steps in "Tuning Procedure" on page 54 to determine if any additional tuning is necessary. Observe the drive output current response on an oscilloscope. If further tuning is necessary or desired, please contact *ADVANCED* Motion Controls before proceeding through the through following steps.

Tune the Current Loop Proportional Gain

1. Follow the steps outlined in "Current Loop Proportional Gain Adjustment" on page 55 up through Step 8.
2. Observe the drive current response on an oscilloscope. Small step tuning is different than large step tuning, so adjust the function generator square wave amplitude so the drive outputs a current step similar to what will be expected in typical operation.
   - If the current response does not rise quickly enough to the step input command, or if it never reaches the input command, the resistance of the current loop proportional

gain resistor will need to be increased. This will increase the current loop proportional gain, and achieve a faster, more aggressive response.

- If the current response overshoots the step input command, the resistance of the current loop proportional gain resistor will need to be decreased. This will decrease the current loop proportional gain, and provide a slower, more stable response.

3. Finding an acceptable resistance may take a few iterations. As outlined in the previous section, using an external potentiometer will make the process easier. Remember to remove power from the drive prior to removing or adding any components to the PCB.
4. Use a resistance value that brings the current response right to the point of overshoot. If there is a large amount of overshoot, or if there are oscillations, decrease the resistance value until there is little or no overshoot. Depending on the application requirements, a little overshoot is acceptable, but should never exceed 10%.
5. When an acceptable resistance value has been found, remove power from the drive.

Tune the Current Loop Integral Gain

1. After the proportional gain resistance has been adjusted to an acceptable value, re-enable the current loop integrator capacitor.
2. Using the same function generator input command as in the previous section, apply power to the drive and observe the current loop response on an oscilloscope.
3. The current loop integrator capacitor can be changed or shorted out of the circuit. Test both settings while observing the current loop response.
   - If the current response square wave oscillates or overshoots, a larger capacitance value is necessary.
   - If the current response square wave corners are too rounded, a smaller capacitance value is necessary to sharpen the corners.
4. Although the ideal current loop response after integral gain tuning will be a critically damped square wave, the application requirements will determine what the desired response will be (i.e. how much overshoot, steady-state error, oscillation, is acceptable).

Velocity Loop Tuning

The velocity loop proportional gain is adjusted by the on-board Loop Gain potentiometer. The velocity loop integral gain can be adjusted similar to the current loop integral gain (capacitance value can be changed, capacitor can be shorted out). As in tuning the current loop integral gain, use larger value capacitors to correct for overshoot or oscillation, and smaller value capacitors for a quicker response time.

B Specifications

B.1 Specifications Tables

TABLE B.1 Power Specifications

Description	Units	AZ_10A4xx	AZ_6A8	AZ_12A8	AZ_20A8	AZ_40A8	AZ_60A8	AZ_10A20	AZ_25A20
DC Supply Voltage Range	VDC	10-36	20-80		10-80			40-175	
DC Bus Over Voltage Limit	VDC	40	88					195	193
DC Bus Under Voltage Limit	VDC	8	18		9			36	
Maximum Peak Output Current	A	10	6	12	20	40	60	10	25
Maximum Continuous Output Current	A	5	3	6	12	20	30	6	12.5
Maximum Power Dissipation at Continuous Current	W	9	12	24	48	80	120	53	110
Minimum Load Inductance	µH	100	100					250	
Switching Frequency[1]	kHz	40	31					20.7	

1. Switching frequency for AZBE/AZBH_40A8 and AZBE/AZBH_60A8 drive models is 33 kHz. Switching frequency for AZBE/AZBH_10A20 and AZBE/AZBH_25A20 is 22 kHz.

TABLE B.2 Control Specifications

Description	AZB	AZBDC	AZBE[1]	AZBH[2]	AZBD
Command Sources	± 10V Analog	PWM and Direction	± 10V Analog	± 10V Analog	± 10V Analog
Commutation Methods	Trapezoidal	Trapezoidal	Trapezoidal	Trapezoidal	Trapezoidal
Control Modes	Current	Current	Current, Duty Cycle, Encoder Velocity, Tachometer Velocity	Current, Duty Cycle, Hall Velocity, Tachometer Velocity	Duty Cycle
Motors Supported	Three Phase Single Phase	Three Phase Single Phase	Three Phase Single Phase	Three Phase Single Phase	Three Phase Single Phase

1. AZBE10A4 models operate solely in Encoder Velocity mode.
2. AZBH10A4 models operate solely in Hall Velocity mode.

TABLE B.3 Feedback Supported

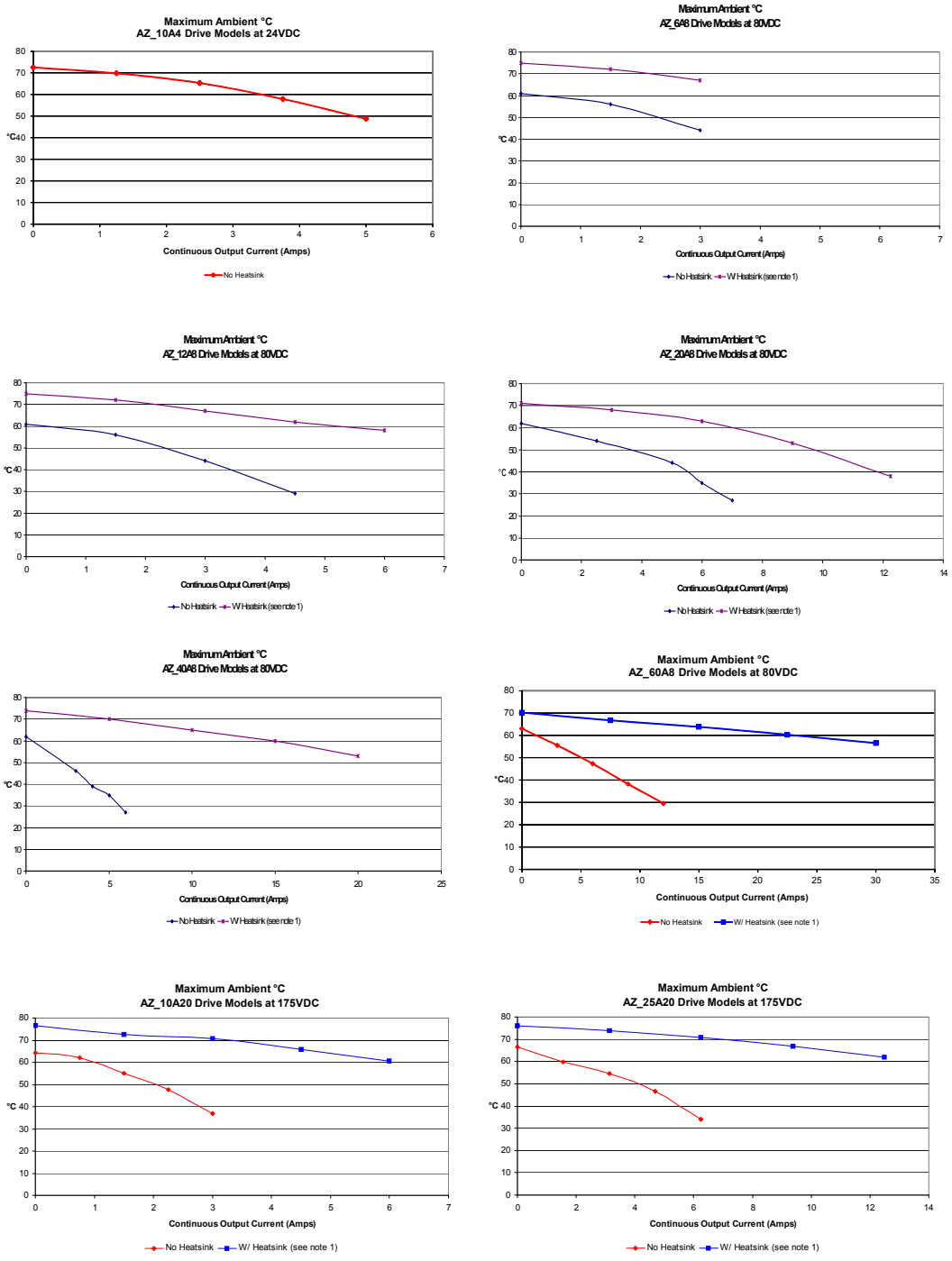
Description	AZB	AZBDC	AZBE	AZBH	AZBD
Hall Sensors for Commutation	✔	✔	✔	✔	✔
Hall Sensors for Velocity Control				✔	
Single- Ended Incremental Encoder			✔		

TABLE B.4 Hardware Protection

Description[1]	All AZ Drives
Over Current	✔
Over Temperature	✔
Over Voltage	✔
Under Voltage	✔
Short Circuit (Phase-Phase)	✔
Short Circuit (Phase-Ground)	✔
Invalid Hall Commutation	✔

1. See "Fault Conditions and Symptoms" on page 68 for more information on hardware protection.

FIGURE B.1 AZ Ambient Temperature Ranges



1. The heatsink used in the above tests is a 15" x 22" x 0.65" aluminum plate.

TABLE B.5 Standard Environmental Specifications

Parameter	Description
Ambient Temperature Range	See Figure B.1
Baseplate Temperature Range	See drive datasheet
Humidity	90%, non-condensing
Mechanical Shock	10g, 11ms, Half-sine
Vibration	2 - 2000 Hz @ 2.5g
Altitude	0-3000m

TABLE B.6 Physical Dimensions

Description	Units	AZ_10A4	AZ_10A4IC	AZ_6A8 / AZ_12A8	AZ_20A8 / AZ_10A20	AZ_40A8 / AZ_60A8 / AZ_25A20
Height	mm (in)	38.1 (1.50)	38.1 (1.50)	63.50 (2.50)	63.50 (2.50)	76.20 (3.00)
Width	mm (in)	38.1 (1.50)	38.1 (1.50)	50.80 (2.00)	50.80 (2.00)	50.80 (2.00)
Depth (not including pin lengths)	mm (in)	7.34 (0.29)	16.6 (0.65)	16.84 (0.66)	22.86 (0.90)	22.86 (0.90)
Weight	g (oz)	8.5 (0.3)	17 (0.6)	84.9 (3.0)	94.5 (3.3)	119.7 (4.2)
Baseplate Thickness	mm (in)	-	-	6.35 (0.25)	5.79 (0.228)	5.79 (0.228)

FIGURE B.2 AZ_10A4 Mounting Dimensions (inches and [mm])

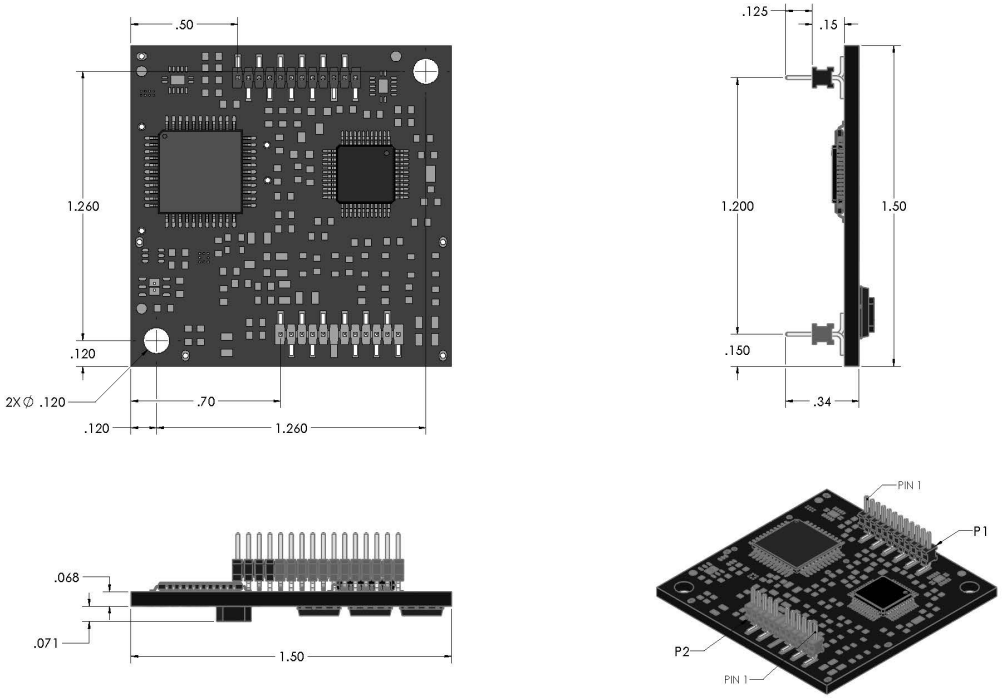


FIGURE B.3 AZ_10A4IC Mounting Dimensions (inches and [mm])

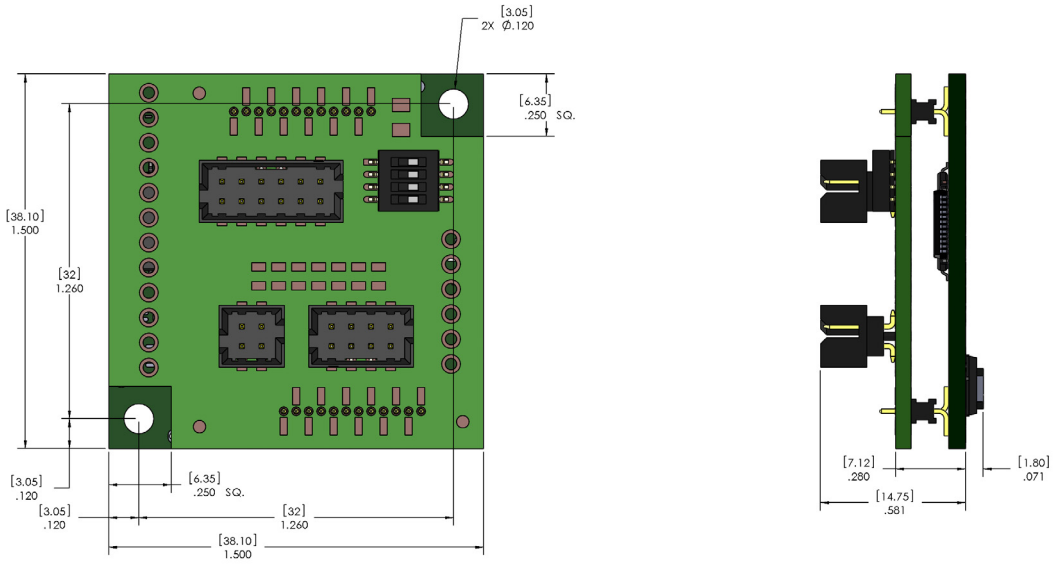


FIGURE B.4 AZBE/H/D10A4 Mounting Dimensions (inches and [mm])

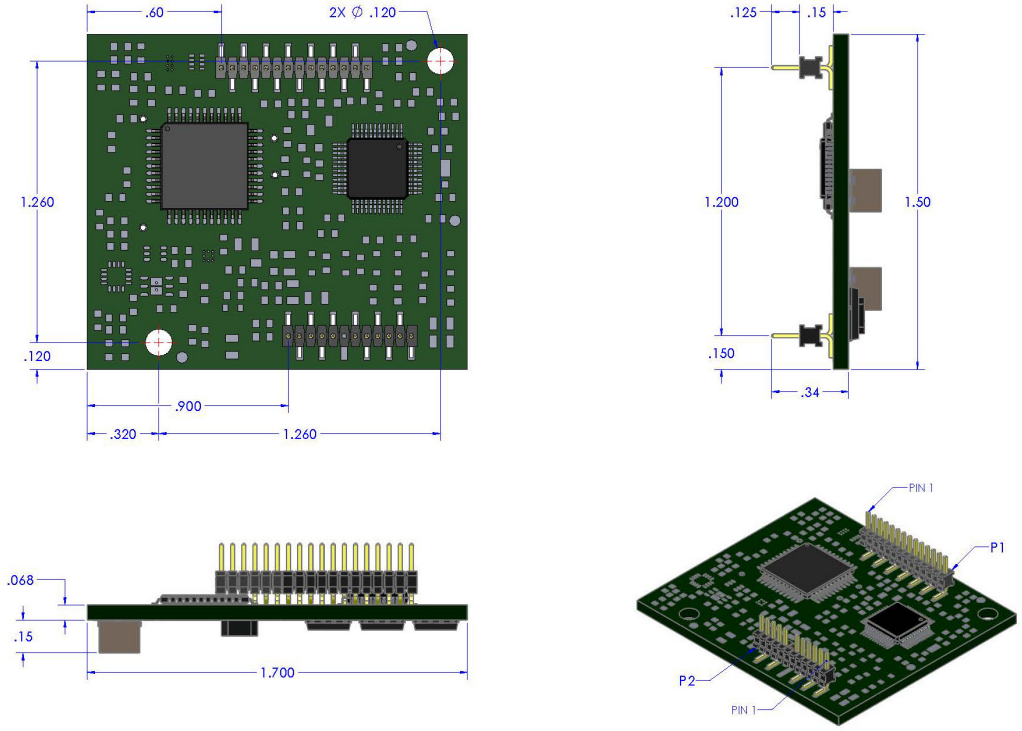


FIGURE B.5 AZ_12A8 / AZ_6A8 Mounting Dimensions (inches and [mm])

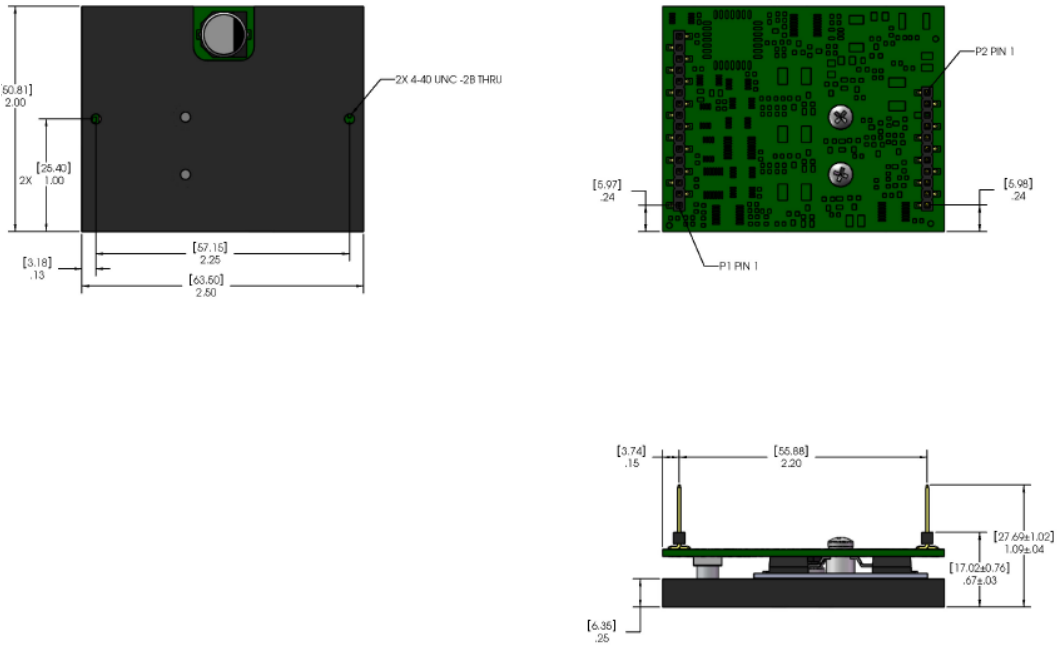


FIGURE B.6 AZ_20A8 / AZ_10A20 Mounting Dimensions (inches and [mm])

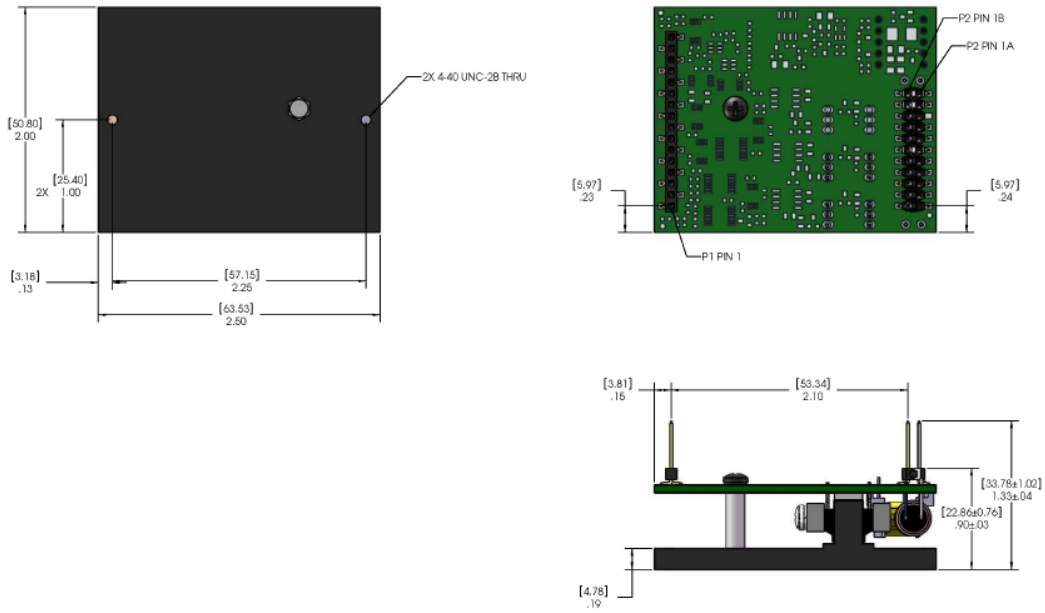
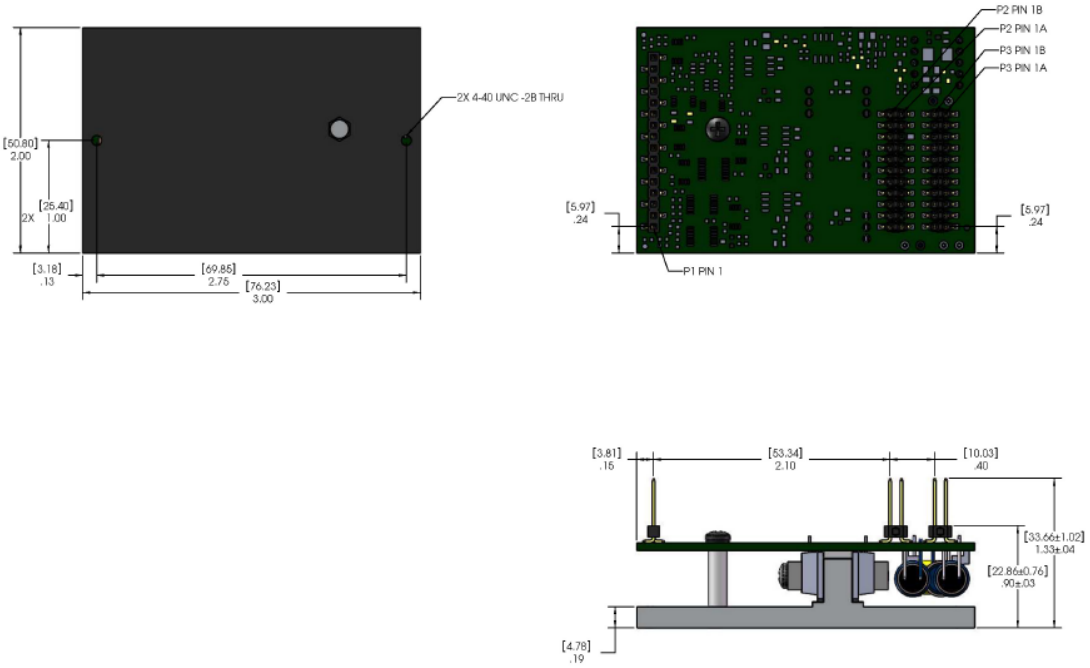


FIGURE B.7 AZ_40A8 / AZ_60A8 / AZ_25A20 Mounting Dimensions (inches and [mm])



C Troubleshooting

This section discusses how to ensure optimum performance and, if necessary, get assistance from the factory.

C.1 Fault Conditions and Symptoms

An inoperative drive can indicate any of the following fault conditions:

- over-temperature
- over-voltage
- under-voltage
- short-circuits
- invalid commutation
- inhibit input
- power-on reset

All of the above fault conditions are self-reset by the drive. Once the fault condition is removed the drive will become operative again without cycling power.

To determine whether the drive is in a fault state, measure the "Fault Output" pin with a digital multimeter or voltmeter. A high at this pin will indicate that the drive is subject to one of the above fault conditions, and the drive will be disabled until the drive is no longer in a fault state. To remove the fault condition, follow the instructions in the sections below describing each possible fault state.

Over-Temperature Verify that the baseplate temperature is less than 75ºC (167º F). The drive remains disabled until the temperature at the drive baseplate falls below this threshold.

Over-Voltage Shutdown

1. Check the DC power supply voltage for a value above the drive over-voltage shutdown limit. If the DC bus voltage is above this limit, check the AC power line connected to the DC power supply for proper value.
2. Check the regenerative energy absorbed during deceleration. This is done by monitoring the DC bus voltage with a voltmeter or oscilloscope. If the DC bus voltage increases above the drive over-voltage shutdown limit during deceleration or regeneration, a shunt regulator may be necessary. See "Regeneration and Shunt Regulators" on page 21 for more information.

Under-Voltage Shutdown Verify power supply voltages for minimum conditions per specifications. Also note that the drive will pull the power supply voltage down if the power supply cannot provide the required current for the drive. This could occur when high current is demanded and the power supply is pulled below the minimum operating voltage required by the drive.

Short Circuit Fault

1. Check each motor lead for shorts with respect to motor housing and power ground. If the motor is shorted it will not rotate freely when no power is applied while it is uncoupled from the load.
2. Disconnect the motor leads to see if the drive will enable without the motor connected.
3. Measure motor armature resistance between motor leads with the drive disconnected.

Invalid Hall Sensor State See the "Commutation Sequence" table in "Hall Sensors" on page 10 for valid commutation states. If the drive is disabled check the following:

1. Make sure that the 60 or 120 degree phasing jumper (JE2) is in the correct setting per motor data sheets. If driving a single phase (brushed type) motor, use the 60-degree phase setting (see "Using a Single Phase Motor" on page 11 for more information on this particular configuration).
2. Check the voltage levels for all the Hall sensor inputs.
3. Make sure all Hall Sensor lines are connected properly.

Inhibit Input Check inhibit input for correct polarity (that is, pull-to-ground to inhibit or pull-to-ground to enable). Inhibit configuration depends on JE1 on the PCB. Also, keep in mind that noise on the inhibit line could be a cause for a false inhibit signal being given to the drive.

Power-On Reset All drives have a power-on reset function to ensure that all circuitry on the board is functional prior to enabling the drive. The board will only be disabled momentarily, and will quickly enable upon power up.

C.1.1 Overload

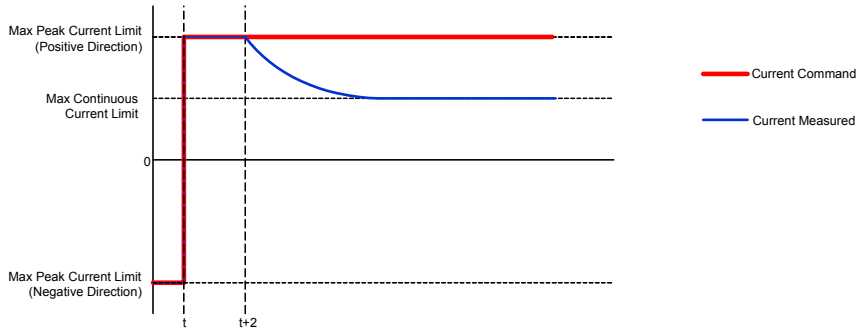
Verify that the minimum inductance requirement is met. If the inductance is too low it could appear like a short circuit to the drive and thus it might cause the short circuit fault to trip. Excessive heating of the drive and motor is also characteristic of the minimum inductance requirement not being met. See drive data sheets for minimum inductance requirements.

C.1.2 Current Limiting

AZ drives incorporate a "fold-back" circuit for protection against over-current. This "fold-back" circuit uses an approximate "I^2t" algorithm to protect the drive.

- Maximum peak current output level can be sustained for about 2 seconds.
- To actually achieve maximum peak current output for 2 seconds requires the current command to fully swing from peak in one direction to the other.

FIGURE C.1 Maximum Peak Current Fold-Back

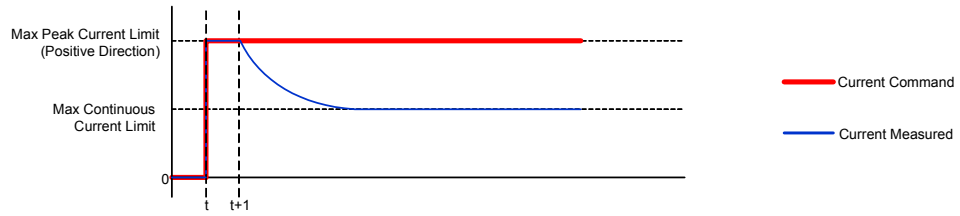


Caution

Sustained maximum current demand, when switching between positive and negative maximum current without allowing sufficient time for fold-back, will result in drive damage. Drive RMS current should be below the continuous current setting!

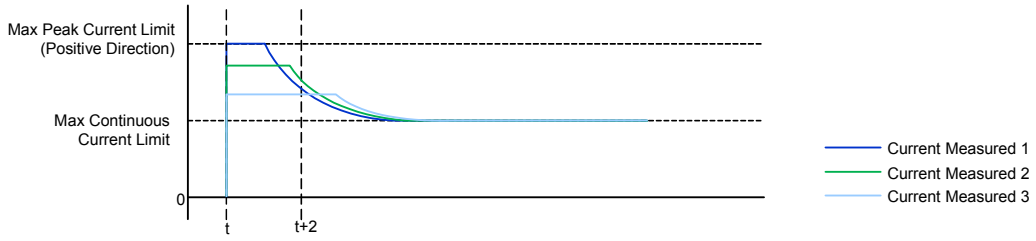
- For most applications, it's a rare occurrence to fully swing from peak in one direction to the other. It is more likely the drive will be commanded from zero to max peak current. Under this condition, the drive will only sustain the maximum peak current for about one second.

FIGURE C.2 Peak Current Fold-Back



- Commanding maximum peak output current starting from above zero command will also yield reduced peak current output time.
- When commanding output current less than the max peak limit, but more than the max continuous limit, the current output can be sustained for a longer time period than a maximum peak command before folding back.

FIGURE C.3 Above Continuous Current Foldback



- The closer the commanded current is to the peak current limit, the shorter the peak output time will be.

- Any command at or below the maximum continuous current limit can be achieved for as long as there are no fault conditions present.
- When the drive is configured for any of the velocity modes, the user is no longer in direct control of the current output. The current commands will be determined by the velocity loop. Though internally the current loop still functions like it is described above, it will do only what is necessary to meet the velocity demand. The current output will be heavily dependent on:
  - How tight the velocity loop is tuned
  - The load characteristics
  - The speed the motor is already turning
  - Magnitude and slope of velocity step

C.1.3 Motor Problems

A motor run-away condition is when the motor spins rapidly with no control from the command input. The most likely cause of this error comes from having the feedback element connected for positive feedback. This can be solved by changing the order that the feedback element lines are connected to the drive, or for AZBH and AZBE drives, changing Switch 4 on the DIP switch bank to the opposite setting.

Another common motor issue is when the motor spins faster in one direction than in the other. This is typically caused by improper commutation, usually because the motor power wires are connected in the wrong order. Try all six combinations of connecting the motor power wires to the drive to find the correct commutation order. The proper combination of motor wires will yield smooth motion and identical speeds in both directions. Improper combinations will cause jerky motion, slow movement in one direction, and/or audible noise. As a final verification that the commutation is correct, use the Velocity Monitor Output pin to measure motor speed in both directions. This can also be caused by invalid Hall Commutation. Check to see if the drive is set for 120- or 60-degree phasing, and whether this setting corresponds to the type of motor being used (typically 120-degree for three phase motors, and 60-degree for single phase motors). See "Hall Sensors" on page 10 for more information.

For a brushless motor, if the opposite motor direction is desired for a given command input, interchange Hall 1 and Hall 3, then Motor A and Motor B.

C.1.4 Causes of Erratic Operation

- Improper grounding (for example, drive signal ground is not connected to source signal ground).
- Noisy command signal. Check for system ground loops.
- Mechanical backlash, dead-band, slippage, etc.
- Noisy inhibit input line.
- Excessive voltage spikes on bus.

C.2 Technical Support

For help from the manufacturer regarding drive set-up or operating problems, please gather the following information.

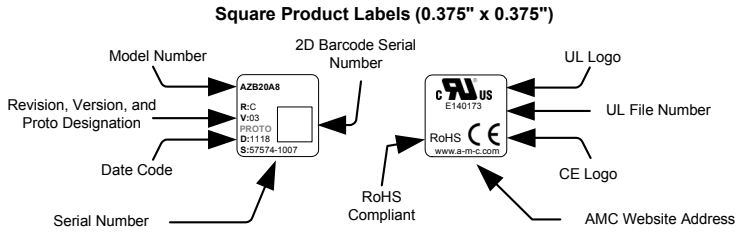
C.2.1 Drive Model Information

- DC bus voltage and range.
- Motor type, including inductance, torque constant, and winding resistance.
- Position of all DIP-switches.
- Length and make-up of all wiring and cables.
- If brushless, include Hall sensor information.
- Type of controller, plus full description of feed back devices.
- Description of problem: instability, run-away, noise, over/under shoot, or other description.
- Complete part number and serial number of the product. Original purchase order is helpful, but not necessary.

C.2.2 Product Label Description

The following is a typical example of a product label as it is found on the drive:

FIGURE C.4 Product Label



1. Model Number: This is the main product identifier. The model number can have a suffix designating a change from the base model.
2. Revision Letter: Product revision level letter ('A' is the earliest release from any model).
3. Version: The version number is used to track minor product upgrades with the same model number and revision letter ('01' is the earliest release of any revision).
4. Proto Designation: When included, indicates that the model is a prototype unit and model number will also begin with an 'X' designator.
5. Serial Number: The serial number consists of a 5-digit lot number followed by a 4-digit sequence number. Each product is assigned a unique serial number to track product life cycle history.
6. Date Code: The date code is a 4-digit number signifying the year and week of manufacture. The first two digits designate the year and the second two digits designate the week (e.g. the drive label shown would have been built in the year 2011 during the 18th week).
7. General Information: Displays applicable agency approvals, UL file reference number, compliance approvals, and EtherCAT capability. More complete product information is availabe by following the listed website.

C.3 Warranty Returns and Factory Help

Seller warrants that all items will be delivered free from defects in material and workmanship and in conformance with contractual requirements. The Seller makes no other warranties, express or implied and specifically NO WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

The Seller's exclusive liability for breach of warranty shall be limited to repairing or replacing at the Seller's option items returned to Seller's plant at Buyer's expense within one year of the date of delivery. The Seller's liability on any claim of any kind, including negligence, for loss or damage arising out of, connected with or resulting from this order, or from the performance or breach thereof or from the manufacture, sale, delivery, resale, repair or use of any item or services covered by or furnished under this order shall in no case exceed the price allocable to the item or service or part thereof which gives rise to the claim and in the event Seller fails to manufacture or deliver items other than standard products that appear in Seller's catalog. Seller's exclusive liability and Buyer's exclusive remedy shall be release of the Buyer from the obligation to pay the purchase price. IN NO EVENT SHALL THE SELLER BE LIABLE FOR SPECIAL OR CONSEQUENTIAL DAMAGES.

Buyer will take all appropriate measures to advise users and operators of the products delivered hereunder of all potential dangers to persons or property, which may be occasioned by such use. Buyer will indemnify and hold Seller harmless from all claims of any kind for injuries to persons and property arising from use of the products delivered hereunder. Buyer will, at its sole cost, carry liability insurance adequate to protect Buyer and Seller against such claims.

All returns (warranty or non-warranty) require that you first obtain a Return Material Authorization (RMA) number from the factory.

Request an RMA number by:

web	www.a-m-c.com/download/form/form_rma.html
telephone	(805) 389-1935
fax	(805) 389-1165

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